SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Instrumentation Fundamentals—Betz

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Aeration Efficiency and Design—Eckenfelder

Industrial Water Conservation—Symposium

Beet Sugar Wastes—Fleming

NOVEMBER, 1952—VOL. 24, No. 11

Make Plans to Attend

TWENTY-SIXTH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

FLORIDA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

MUNICIPAL (BAYFRONT PARK) AUDITORIUM

MIAMI, FLORIDA

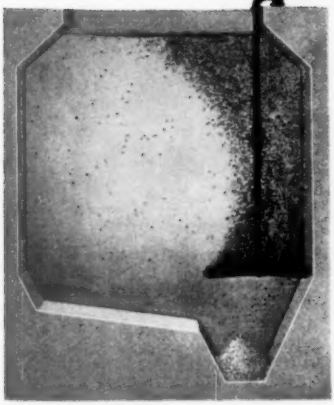
October 13-16, 1953

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

325 ILLINOIS BUILDING CHAMPAIGN, ILLINOIS

CHICAGO SEWAGE EQUIPMENT

Chicago AER-DEGRITTER



The only method of removing grit and sand from sewage without mechanical equipment is provided by the Chicago Aer-Degritter. The velocity of flow is controlled by air introduced through Chicago Swing Diffusers and Precision Diffuser Tubes. All sand of 0.2 mm. (65 mesh) and larger is washed and deposited in the bottom of the tank.

Less than 10% volatile matter and only a negligible trace of putrescible organics remains in the grit removed. Aer-Degritters may be installed ahead of all mechanical equipment because coarse sewage material will not interfere with the operation of the Aer-Degritter or affect the hydraulic design of the plant.

Here are the basic features of the Chicago Aer-Degritter.

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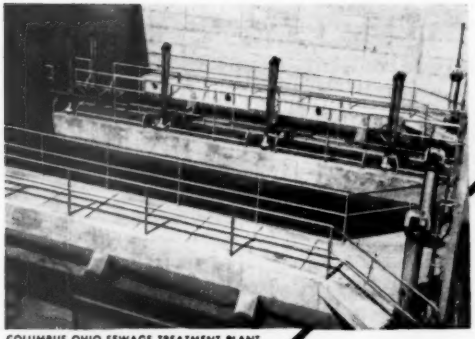
- NO MECHANISM
- LOW COST
- SIMPLE STRUCTURE
- AIR CONTROLLED VELOCITIES INDEPENDENT OF FLOW

52 INSTALLED IN TWO YEARS



COLUMBUS OHIO SEWAGE TREATMENT PLANT
Design Flow 160 M.G.D.
PAUL A. UHLMANN & ASSOCIATES
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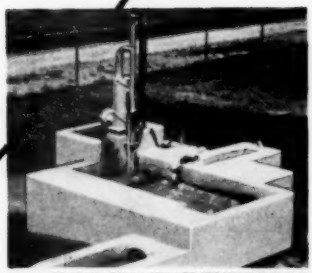

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Design Flow 8 M.G.D.
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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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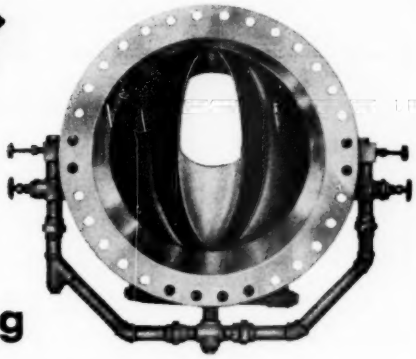

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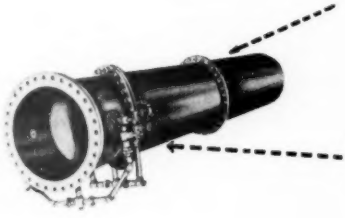
Assures accurate measurement of sewage, sludge, or trade wastes at low velocity . . . even under low pressure! Throat ellipse's major dimension is vertical—equal to diameter of circular main section.



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—prevents accumulations of air or gas that under certain conditions could impede flow and distort measurements.

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—a flat straight bottom, self-scouring of sediments or solids.

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in conjunction with

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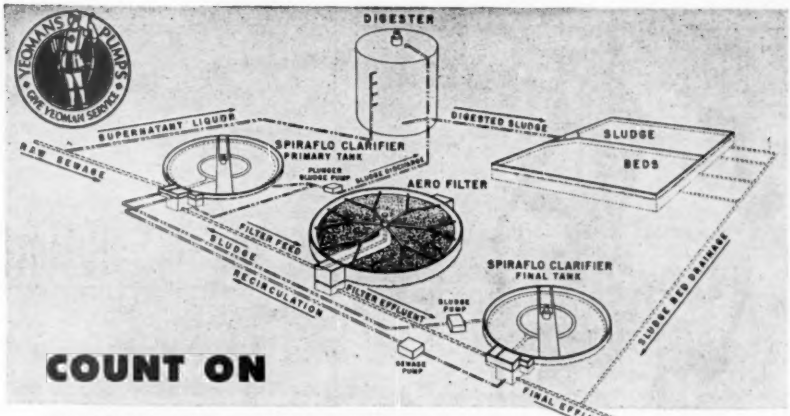
Municipal (Bayfront Park) Auditorium, Miami, Florida

October 13–16, 1953

Association	*Place*	*Time*
Pacific Northwest Sewage and Industrial Wastes Assn.	Multnomah Hotel, Portland, Ore.	Oct. 23–24, 1952
The Canadian Institute on Sewage and Sanitation	Seigniory Club, Montebello, Que.	Nov. 3–5, 1952
New England Sewage and Industrial Wastes Assn.	Taunton Inn, Taunton, Mass.	Nov. 5, 1952
North Carolina Sewage and Industrial Wastes Assn.	Skyland Hotel, Hendersonville, N. C.	Nov. 10–12, 1952
Florida Sewage and Industrial Wastes Assn.	San Carlos Hotel, Pensacola, Fla.	Nov. 16–19, 1952
Oklahoma Water, Sewage and Industrial Waste Conference	Student Union, Okla. A & M College, Stillwater, Okla.	Dec. 1–5, 1952
New York Sewage and Industrial Wastes Assn.	Hotel New Yorker, New York City	Jan. 22–23, 1953
Texas Water and Sewage Works Assn.	Texas A & M College, College Station, Tex.	Mar. 8–12, 1953
New Jersey Sewage and Industrial Wastes Assn.	Hotel Traymore, Atlantic City, N. J.	March 11–13, 1953
Arkansas Water and Sewage Conference	Hotel Marion, Little Rock, Ark.	Mar. 16–18, 1953
South Carolina Water and Sewage Works Assn.	Clemson College, Spartansburg, S. C.	Apr. 2–4, 1953
Kansas Sewage and Industrial Wastes Association	Hotel Broadview, Wichita, Kans.	Apr. 22–24, 1953
California Sewage and Industrial Wastes Association	Mar Monte Hotel, Santa Barbara, Calif.	Apr. 22–25, 1953
Arizona Sewage and Water Works Assn.	San Marcos Hotel, Chandler, Ariz.	Apr. 23–25, 1953
Central States Sewage and Industrial Wastes Assn.	Hotel Pere Marquette, Peoria, Ill.	June 3–5, 1953
Pennsylvania Sewage and Industrial Wastes Assn.	Pa. State College, State College, Pa.	Aug. 26–28, 1953



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• 7-day average overall plant reduction—Suspended Solids 91.5%, B.O.D. 92%—a typical operational report

	Sewage Flow M.G.D.	Raw Sewage		Primary Effluent				Final Effluent				Overall Plant Reduction	
		Sus. Solids PPM	B.O.D. PPM	Sus. Solids PPM	Per Cent Reduction	B.O.D. PPM	Per Cent Reduction	Solids PPM	Per Cent Reduction	B.O.D. PPM	Per Cent Reduction	Sus. Solids Per Cent	B.O.D. Per Cent
6-15	0.2996	210	255	79	62.4	136	46.6	28	64.6	18	86.8	86.6	93.0
6-16	0.2467	425	260	85	80.0	127	51.2	23	73.0	19	85.1	94.6	92.6
6-17	0.2554	410	235	124	69.7	141	40.0	28	77.4	18	87.3	93.3	92.4
6-18	0.2487	308	222	76	75.4	108	51.4	34	55.3	16	85.2	89.0	92.8
6-19	0.1753	222	218	64	71.2	132	39.5	17	73.5	—	—	92.4	—
6-20	0.2666	262	320	88	66.4	147	54.1	20	77.3	30	79.6	92.4	90.6
6-21	0.2279	240	215	78	67.5	138	35.8	19	75.7	20	85.7	92.0	90.7
Average	0.2456	297	247	85	70.5	132	45.5	24	71.0	20	85.0	91.5	92.0

* Name of plant on request.

"Spiraflo" Advantages

- Increased B.O.D. and settleable solids removal—influent is introduced tangentially into annular race around the periphery. Sewage spirals downward slowly and enters main clarification compartment at the bottom of the tank. Uniform, slow diffusion of waste under the skirt results in greatly reduced velocities and provides maximum removal of settleable solids.
- Greater removal of finely divided particles—due to upward flow through sludge blanket. This increases flocculation and results in more effective removal of finely divided particles before waste enters the effluent weirs.

"Aero-Filter" Advantages

- Straight-wall design minimizes construction costs.
- Thorough uniform distribution—therefore costly recirculation for dilution is unnecessary.
- Operating cost is lowest of any type of complete sewage treatment.
- Uninterrupted and almost complete momentary bed coverage minimizes troubles from odors, freezing, ponding, filter flies.
- All returns made direct to the filter—no oversize primary tank required.

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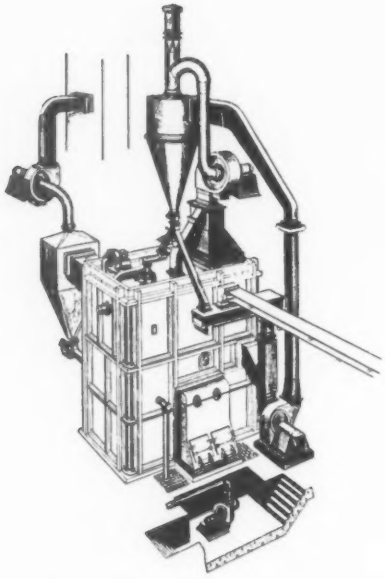

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C-E systems now in service are meeting the requirements of both large and small communities – serving equivalent populations from 6,000 to 3,600,000. The list below shows the most recent installations.

C-E Raymond Systems are flexible in layout, highly efficient and fully reliable; they provide for maximum utilization of waste heat. They mean for any community the end of stream or atmospheric pollution resulting from the disposal of sewage wastes.

The services of C-E specialists are available to help you plan for the most practical and economical answer to your sludge disposal problems. For prompt attention, get in touch with one of the Combustion offices listed below.

C-E Raymond Systems installed, under construction or on order since 1945

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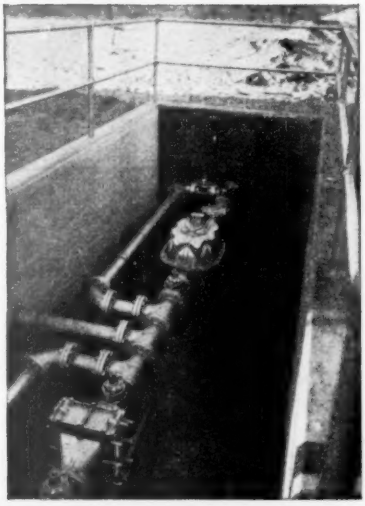


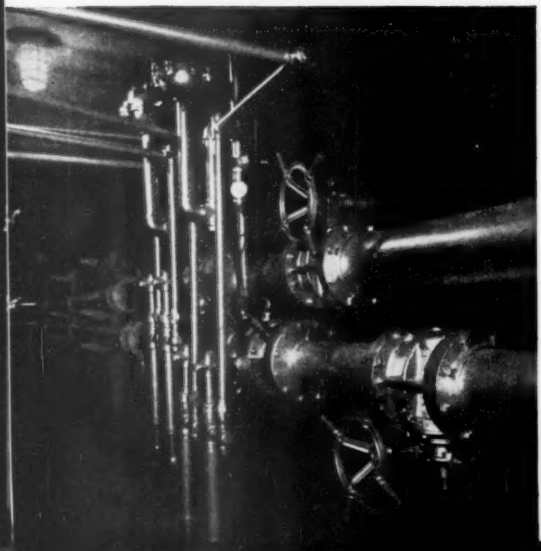
Rockwell built meter and Nordstrom valves in pit installation.

Gear operated Nordstrom valves at Venturi meter

Valves take plenty of abuse in sewage treatment plant metering line service . . . But Nordstroms last and last.

One reason is that flow that attacks seats of ordinary valves *can't even reach* a Nordstrom valve seat; it's never exposed. This one Nordstrom feature alone eliminates a lot of costly maintenance and valve replacements.

Write for Bulletin No. 1031 describing Rockwell-built Nordstrom valves, gas meters and water meters for sewage service. Rockwell Manufacturing Company, 400 N. Lexington Ave., Pittsburgh 8, Pa.



TYPICAL NORDSTROM SERVICES IN SEWAGE TREATMENT PLANTS

Lateral Air Lines	Water Metering Lines
Sludge Lines	Digester Lines
Grit Chamber Drain Valves	Bucket Elevator Lines
Pump Suction and Discharge	Sewage Gas
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Rockwell Built Nordstrom Valves

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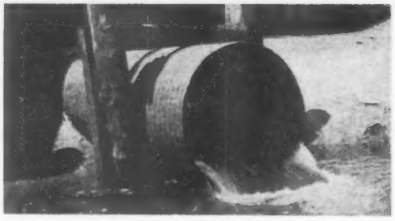
This Sewer Pipe Has a Choice of "Wardrobe"

Just as you change your clothes to fit the weather Armco Corrugated Metal Pipe has three degrees of protection for sewer applications. The type of service determines which should be "worn."

Standard Armco Galvanized Pipe is fine for normal sewer service; Armco ASBESTOS-BONDED Pipe brings severe corrosion to a halt; and PAVED-INVERT Pipe says "no" to erosion.

All have the same basic installation advantages. These are: Light weight, ease of handling, fast assembly, positive-joint bolted couplings, and ample strength without excess bulk.

Whether you are building new sewers or repairing old ones, Armco Corrugated Metal Sewer Pipe has many economical advantages. Write for details. Armco Drainage & Metal Products, Inc., 2572 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation.



NORMAL sewer service is taken in stride by Armco Plain Galvanized Pipe.

SEVERE CORROSION difficulties are solved with Armco ASBESTOS-BONDED Pipe.

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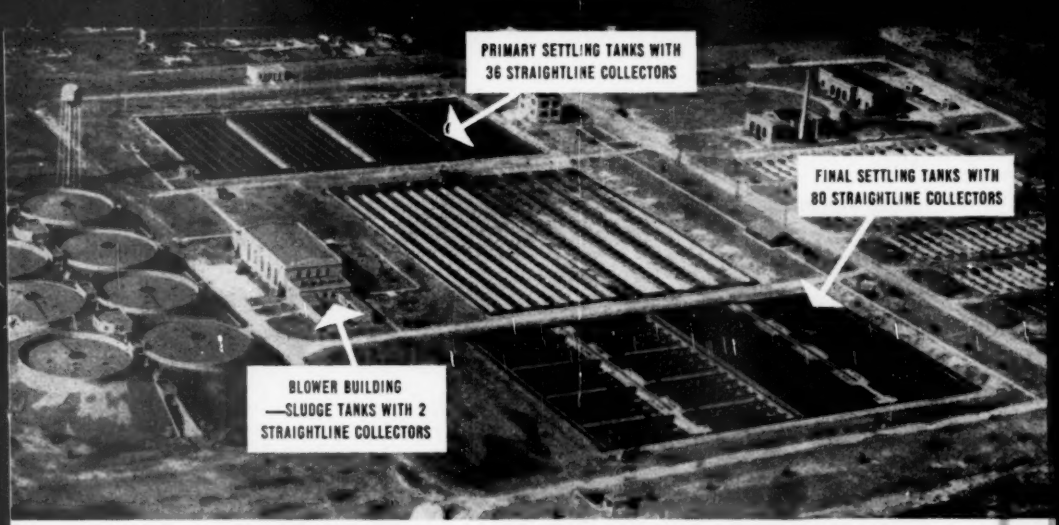
ARMCO SEWER PIPE



Now serving 669,000 people, Philadelphia's Northeast Works has a daily flow of 91 mgd. Capacity is 125 mgd, sufficient to meet the needs of the 876,000 population anticipated by 1970.

It's Straightline Collectors at big, new Philadelphia sewage treatment plant

pecify time-proven LINK-BELT equipment for 25,000,000 gpd Northeast Works

AS on so many important sewage treatment projects, ink-Belt Straightline Sludge Collectors were specified roughout the new Northeast Sewage Treatment Works y the Philadelphia Bureau of Engineering.

For no other collector can match Straightline's proven ecord of uninterrupted operation with minimum atten- ion. Since the first Straightline Collector went into ervice in 1921, a total Straightline capacity of 2 billion pd has been installed.

Straightline action provides the shortest possible travel f collected material at slow, uniform speeds. Result: minimum disturbance of flow and maximum efficiency in removal of solids.

Straightline Collectors are part of the complete Link-Belt line of quality equipment. Whether your job is large or small, our sanitary engineers are glad to work with your engineers, chemists and consultants. Their broad experience will help you get the best in modern water, sewage or industrial liquids treatment.

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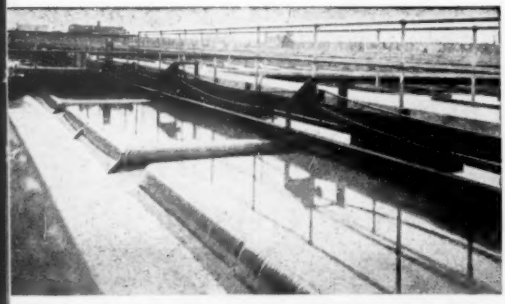
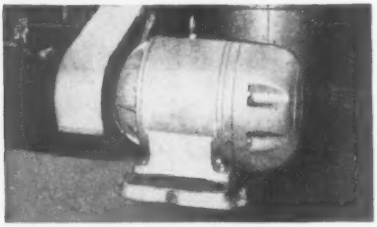
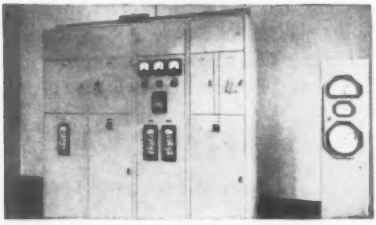


Four traveling Link-Belt Scum Skimmers at the effluent end of Northeast Works' 4 primary settling tanks are driven through Link-Belt Gearmotors. The 28 longitudinal and 8 cross sludge collectors are also Straightline design.

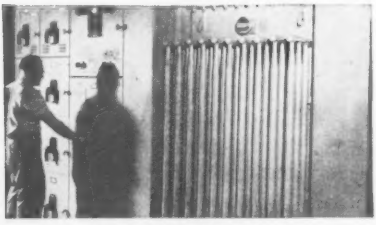
Sixteen final settling tanks at new Philadelphia sewage treatment plant are equipped with 64 longitudinal and 16 cross Link-Belt Straightline Sludge Collectors. The two sludge storage-concentration tanks also have Straightline Collectors.



Motors



Control



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G-E application engineers select products like these to form the co-ordinated electrical system that exactly fits your plant requirements.

Here's Help on Your Campaign for

CLEAN WATERS

General Electric helps make your pollution-control program a success in three ways:

1. Aids you in winning public support through the G-E packaged program "Modern Sewage Treatment" including the color sound movie *Clean Waters.*

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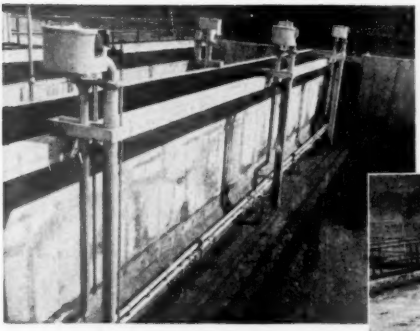
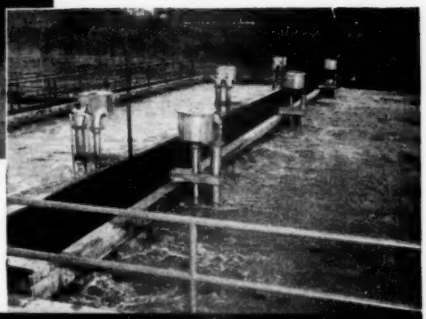


DIFFUSAIR installation at Kirkwood, Mo. Impingement nozzles and bowls are on headers at lower left side of tank.



DIFFUSAIR at Kirkwood, Mo. in operation showing effective "spiral flow" agitation and aeration of tank liquor.

impingement aerator **DIFFUSAIR**

FOR

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WASTE AND

WATER TREATMENT

PRE-AERATION . . .

ACTIVATED SLUDGE . . .

CARBONATION

The Impingement Aerator is a unit developed to accomplish more effectively and economically the diffusion of air as small bubbles to agitate and oxygenate aeration tank liquors.

The principle involved is the combining of a low velocity jet of tank liquor and large air bubbles within an open bowl-like impinger. The cavitation effect thus produced divides the air into smaller bubbles than those diffused from a No. 30 permeability porous tube. The amount and pressure of the impingement water is very low when compared with the progressive back pressuring of the blower that persists when other types of air diffusers are employed.

The impingement liquor is derived directly from the aeration tank mixed liquor, and is lifted with a simple air-lift unit from which 1/3 of the fine air is re-entrained and utilized for oxygenation.

The air is released along headers through 3/16 inch orifices in the impinger units and no air clogging is possible. No filtering of the compressed air supply is required since there are no fine diffusion pores to become clogged.

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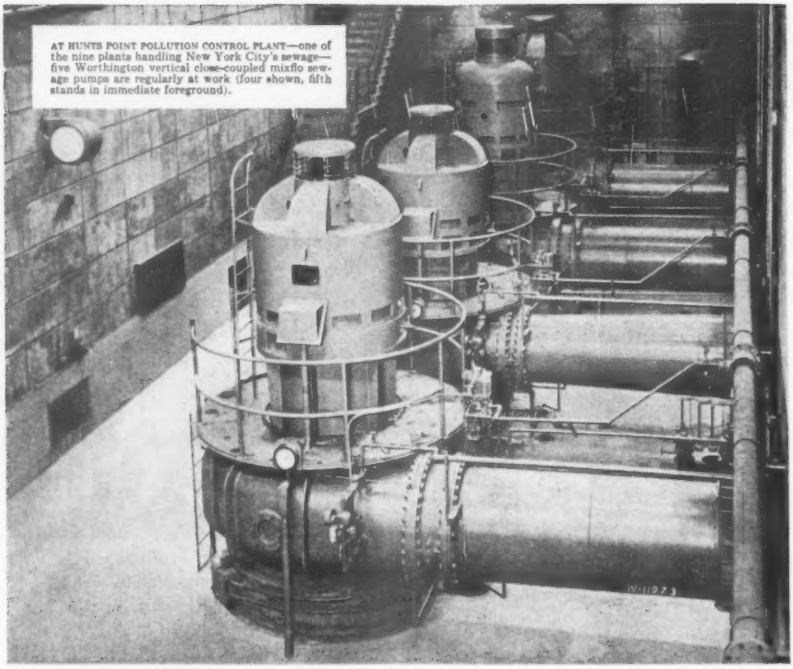


AT HUNTS POINT POLLUTION CONTROL PLANT—one of the nine plants handling New York City's sewage—five Worthington vertical close-coupled mixflo sewage pumps are regularly at work (four shown, fifth stands in immediate foreground).

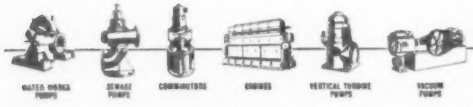
1689 mgd of New York City's Treated Sewage handled by Worthington pumps

If you want to see Worthington sewage pumps—large and small—at work, you can't go wrong by looking inside six of the nine major disposal plants that serve the City of New York. A total of 1689 mgd installed capacity of Worthington sewage pumps are now in regular use in the world's largest city.

New York's installed capacity of sewage pumps is among the largest in the U. S., so you'd naturally expect the city's public works officials to be familiar with Worthington performance—performance that years ago gave Worthington its position as world leader in the manufacture of pumping equipment.

Hundreds of *smaller* municipalities across the country know Worthington, too, not only for sewage pumps but for water-works pumps, comminutors, engines and other public works equipment. *Worthington Corporation, Public Works Division, Harrison, New Jersey.*

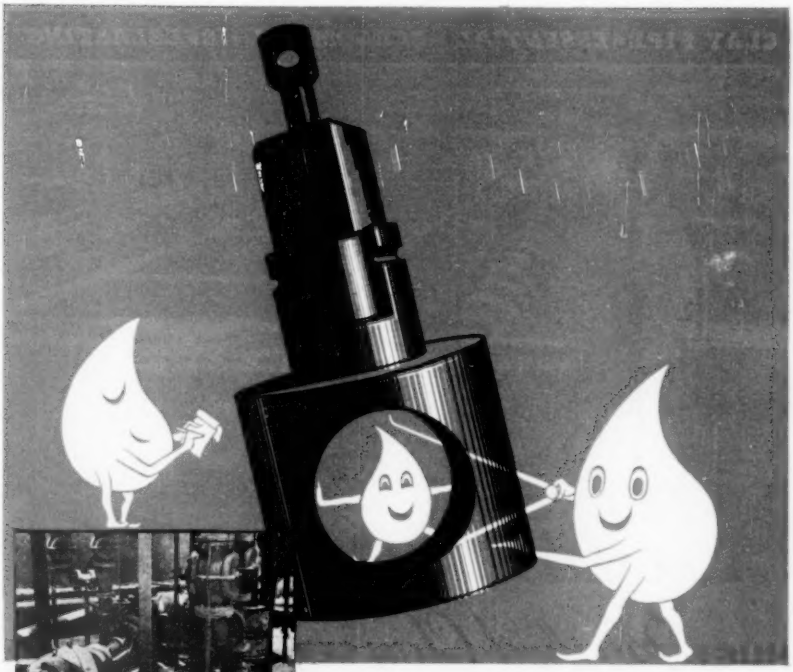
W-2.3



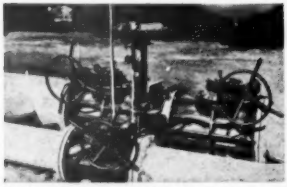
All Major Public Works Equipment Under One Responsibility

WORTHINGTON

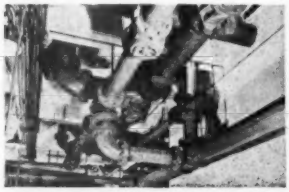
Public Works Equipment



IN THE CHEMICAL and INDUSTRIAL PROCESSING FIELD a.c.f. Round Port CYLINDRICAL Plug Valves handle abrasive ladings, such as cement slurry, coal wash water, etc., without erosion—and have long life.



IN PETROLEUM and GAS INSTALLATIONS a.c.f. Valves give full-area flow with fast, positive shut-off.



IN SEWAGE PLANTS the a.c.f. CYLINDRICAL Plug shears obstructions on raw sewage lines . . . provides uninterrupted flow.

FULL PIPE SIZE AREA

a.c.f.'s Full Round Port, CYLINDRICAL Plug Valve has a straight level-through flow passage the same size and shape as the pipe itself! This means fast unobstructed flow of heavy or viscous ladings, solids in suspension, all liquids and gases.

And—there is full straight-through pipe area in a.c.f.'s Rectangular Port, CYLINDRICAL Plug Valve, too.

Investigate—you need "full pipe size area" valves for economical processing.

a.c.f. CYLINDRICAL FULL PIPE AREA PLUG VALVES

Write for Catalog A-51, American Car and Foundry Co. Valve Division, 1501 E. Ferry Ave., Detroit 11, Michigan

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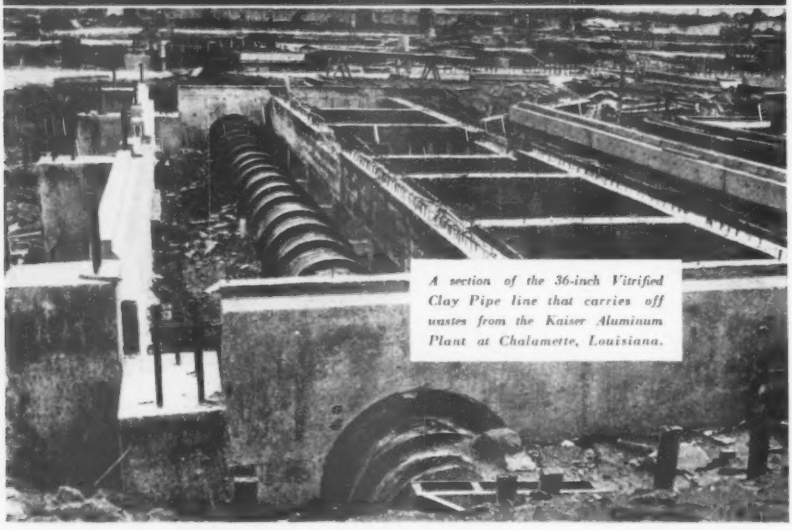
CLAY PIPE—*ESSENTIAL • ECONOMICAL • EVERLASTING*



A section of the 36-inch Vitrified Clay Pipe line that carries off wastes from the Kaiser Aluminum Plant at Chalamette, Louisiana.

HUGE *Vitrified Clay* SEWERAGE SYSTEM serves the New Kaiser Aluminum Plant

KAISER Aluminum and Chemical Corporation's new plant has started to add to the nation's critical supply of basic aluminum. By the end of 1953, the multi-million dollar plant will be producing 200,000 tons of the vitally-needed metal annually.

Industrial wastes, high in fluorine and hydrochloric acid content, are reliably handled by an 11,500 ft. system of Vitrified Clay Pipe.

In *every* city where industrial wastes flow into municipal sewers, Vitrified Clay Pipe is the *one* chemically inert material you can count on for unfailing service. Acids and alkalies can't effect it — today or fifty years from now. *It never wears out.*

NATIONAL CLAY PIPE MANUFACTURERS, INC.

311 High Long Bldg., 5 E. Long St., Columbus 15, Ohio
705 Ninth & Hill Bldg., Los Angeles 15, Calif.
100 N. LaSalle St., Rm. 2100, Chicago 2, Ill.
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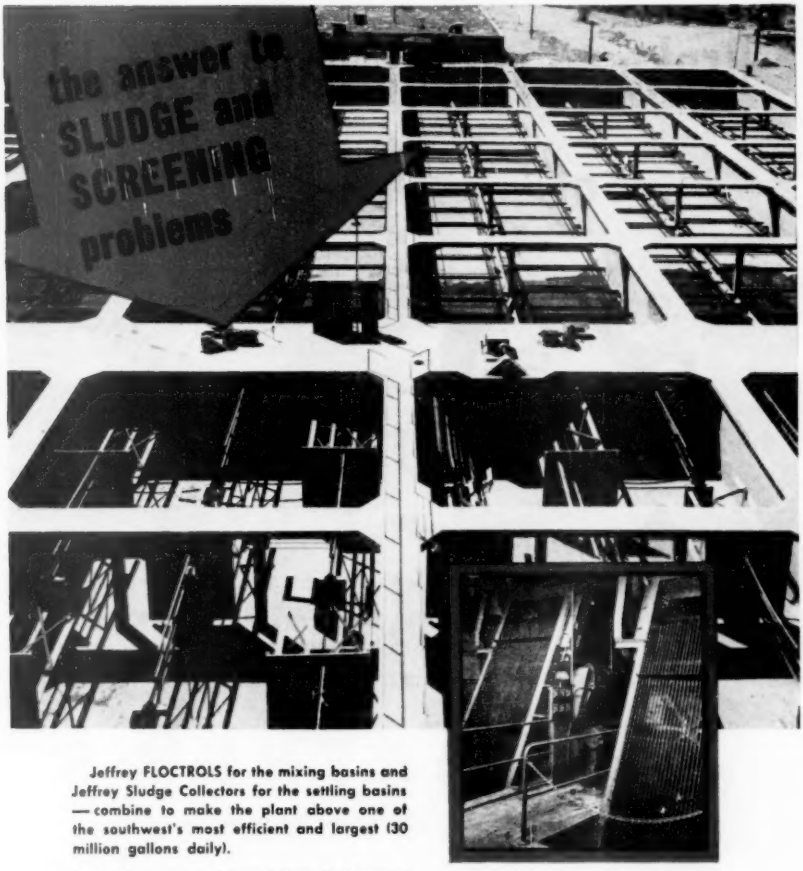
Wherever Reliable Performance-Proved Pipe Is Needed, Specifications Call for Vitrified Clay

Orlando, Fla. (Air Force Base)	74,000 ft.
Morrisville, Pa. (New Steel Defense Plant)	300,000 ft.
Rapid City, S. D. (Air Force Base)	54,000 ft.
Tucson, Ariz. (Air Force Base)	440,000 ft.
Panama City, Fla. (Municipal Expansion)	450,000 ft.
Limestone, Maine (Air Force Base)	65,000 ft.
Rantoul, Ill. (Chanute Field)	158,000 ft.
Bakersfield, Calif. (Municipal Expansion)	313,000 ft.

Vitrified
CLAY
CLAY PIPE NEVER WEARS OUT!
PIPE

C-452 2



Jeffrey FLOCTROLS for the mixing basins and Jeffrey Sludge Collectors for the settling basins — combine to make the plant above one of the southwest's most efficient and largest (30 million gallons daily).

Insert shows two of four Jeffrey Backcleaned Fine Screens in the 26th Ward Sewage Treatment Works, New York City. Jeffrey pioneered this type of screen, has made many installations in the last eleven years.

Other Jeffrey sanitation equipment includes Grit Washers, Scum Removers, Garbage and Screenings Grinders, Chemical Feeders, Chains, etc.

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THE JEFFREY MANUFACTURING COMPANY
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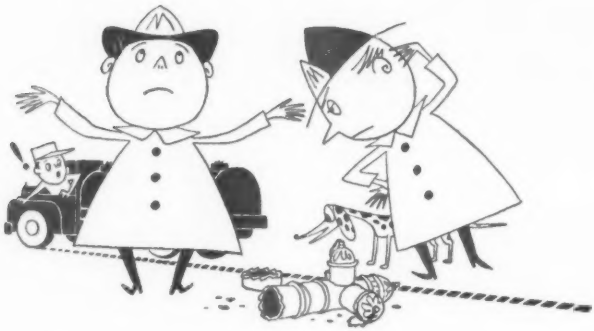

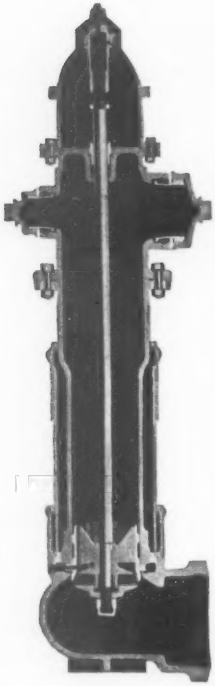

The main valve opens against water pressure and closes with it. This is foolproof protection against flooding when hydrants are broken in traffic accidents.

MATHEWS
HYDRANTS

Made by R. D. Wood Company Public Ledger Building, Independence Square, Philadelphia 5, Pa. Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves.

Mathews Modernized Hydrants . . . Tops in Convenience and Dependability Compression-type valve prevents flooding • Head turns 360° • Replaceable head • Nozzle sections easily changed • Nozzle sections raised or lowered without excavating • Protection case of "Sand-Spun" cast iron for strength, toughness, elasticity • Operating thread only part to be lubricated • All working parts contained in barrel • A modern barrel makes an old Mathews good as new • Available with mechanical joint pipe connections

Aero-Accelator and Biosorption Process

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For best results use the team that goes together *best*... Infilco's BIOSORPTION PROCESS and the AERO-ACCELATOR.

The BIOSORPTION PROCESS has shown phenomenal results in the reduction of B.O.D. and suspended solids. So also are the results in efficiency, low maintenance and appreciable space-savings. The advantages of the AERO-ACCELATOR as a combined mixer-clarifier have been proved in many diversified installations. Together these two form a winning team.

Ask for bulletins describing Infilco's BIOSORPTION PROCESS and the AERO-ACCELATOR. See how the combination of these two can pay out handsomely.

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INFILCO INC. *Tucson, Arizona* | *Plants in Chicago & Joliet, Illinois*

FIELD ENGINEERING OFFICES IN 26 PRINCIPAL CITIES

96%

ARE
STILL IN SERVICE

We are stating a fact and you don't have to take our word for it. We refer you to one of the most important fact-finding jobs ever undertaken by the water works industry — the recently completed survey of the service life of water works facilities. This survey was sponsored by three water works associations.

The survey shows that 96% of all the cast iron water mains ever laid by 25 representative cities in sizes 6-inch and larger *are still in service.*

A detailed report of the survey has recently been published by the American Water Works Association. We have reprinted, by permission, the facts pertaining to cast iron water mains in a brochure which will be sent on request. Write to Cast Iron Pipe Research Association, Thomas F. Wolfe, Managing Director, 122 South Michigan Ave., Chicago 3, Ill.

CAST IRON

CAST IRON PIPE SERVES FOR CENTURIES

SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 24 **November, 1952** **Number 11**

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W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois

Herbert P. Orland, *Associate Editor* Dr. F. W. Mohlman, *Advisory Editor*

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Plant Operators are all talking about the Low Maintenance Costs with

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And the talk is based on *fact* . . . actual studies of Dorr Clarifiers in operation over a period of years.

For example, look at Cleveland, Ohio's Easterly Treatment Plant — where sixteen 112′ dia. Dorr Clarifiers have been in operation since 1932. The figures below are based on actual and accurate plant records — and they're typical of the kind of repair costs you can expect with Dorr units.

Repair costs are one of the primary factors upon which Clarifier excellence should be judged. Are you getting the best?

We'd like to tell you how Dorr Clarifiers stack up on performance too. Ask a Dorr Engineer for the facts.

16 Dorr Sifeed* Clarifiers, for handling 123 M. G. D. of activated sludge at Easterly Treatment Plant, Cleveland, Ohio.

*Reg. U. S. Pat. Off.

13-Year Repair Cost Record for 16 DORR Clarifiers

Years of Operation	13
Total Repair Cost	$848.83
Repair Cost *per unit*	$ 53.05
Repair Cost, per unit, *per year*	$ 4.08
% of Original Cost spent for all repairs in 13 years	0.6%

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Sewage Works

FUNCTIONAL ASPECTS OF SEWAGE PLANT INSTRUMENTATION *

By Jack M. Betz

Civil Engineer, Bureau of Engineering, City of Los Angeles, Calif.

The discussion of sewage plant instrumentation in this paper is divided into three main sections, as follows:

1. Measurement.
2. Remote transmission.
3. Automatic control.

Before proceeding with these subjects, however, there is one other major factor, cost, which requires at least brief comment.

Cost

The cost of adequate instrumentation is a very small portion of the construction cost of a treatment plant and, if properly integrated with the plant units, can go far towards paying its own way. The writer has seen some published data indicating that the cost of instrumentation should be about 5 per cent of the plant cost. This does not appear to be excessive. A large plant should be able to reduce this figure considerably, for an instrument to measure the level in a 3-m.g. digester is no more expensive than one for a 0.5-m.g. tank. At the Hyperion plant in Los Angeles the installed cost of all instrumentation equipment approximated $500,000, which is about 1 per cent of the plant cost. Therefore, if large plants can lower the 5 per cent figure, perhaps small plants should be entitled to exceed it somewhat. A compilation of cost figures in this regard would be of interest and value.

Measurement of Flow

The most common variables requiring measurement and/or control in a sewage treatment plant are flow, liquid level, and temperature. This paper deals almost exclusively with these quantities.

The primary elements most frequently employed to measure flow are the differential producers. These types of elements actually do not measure flow directly, but rather, through measuring the velocity head, the velocity of flow is determined. The velocity, when multiplied by the proper area, will yield the flow rate. It is obvious, then, that this area must be determined and must be unchanging. These considerations limit the differential producers to conditions involving closed, generally circular, conduits flowing full, although rectangular conduits can be traversed using a Pitot tube.

The most usual forms of differential producers are the Venturi tube and the orifice plate. Other forms are generally modifications of these basic units. The most outstanding advantages of the Venturi tube as compared to the orifice plate are: (a) It can be used to measure flows containing solids, such as sewage sludges; and (b) it is very efficient in terms of permanent loss of head.

To counter these advantages, the orifice plate has one marked feature: when compared to the cost of a Venturi tube, the orifice plate is practically

* Presented at 1952 Annual Meeting, California Sewage and Industrial Wastes Assn.; Santa Cruz, Calif.; Apr. 23–26, 1952.

TABLE I.—Performance Characteristics of Hypothetical Measuring Unit

Flow Rate (g.p.m.)	Differential (in.)[1]	Accuracy of Diff. Sensing (in.)[1]	Accur. of Flow Reading	
			(g.p.m.)	(%)
(a) Initial Flow Range				
Max. 1,000	50.00	0.20	2.0	0.2
Av. 400	8.00	0.20	5.2	1.3
Min. 200	2.00	0.20	10.0	5.0
(b) Reduced Flow Range				
Max. 500	12.50	0.20	4	0.8
Av. 200	2.00	0.20	10	5.0
Min. 100	0.50	0.20	18	18.0

[1] Inches of water.

free. This advantage has many ramifications, one of the most important being the adaptability to a new flow range.

When selecting a flow measuring device for a new installation, one important and often difficult decision to be made is the proper flow range. When the maximum flow rate cannot be accurately determined, the natural tendency on the part of the designer is to overstate the maximum flow. This tendency is unfortunate, and in many cases can result in inaccurate metering and completely unsatisfactory automatic control. As will be pointed out later, the system would actually be more flexible and easier to correct if the flow rate were underestimated.

If it is desired to change the range of flow, a new orifice plate of the proper size can be substituted inexpensively. Plants with a suitable machine shop can even manufacture their own orifice plates. However, changing a flow range by changing a Venturi tube is, of course, extremely expensive. An increased range can often be accomplished by altering certain features of the secondary instrument; however, a decreased range is likely to produce differentials so small as to render accurate metering impossible.

To illustrate this fact, consider a Venturi tube or orifice plate which was designed for a flow range of 200 to 1,000 g.p.m., with an average flow of 400 g.p.m. If the unit produced a differential of 50 in. of water at maximum flow, Table I (*a*) gives the performance characteristics. It should be noted that the accuracy of the flow reading is based on the accuracy of the differential sensing device, which has been assumed to be ± 0.20 in. of water. This seems to be a rational basis for evaluating accuracies.

Now, assume that it is desired to reduce the flow range to one-half of the above values. Table I (*b*) gives the resulting performance. The error shown in Table I (*b*) for average flow (5 per cent) is undesirable and the error for minimum flow (18 per cent) is so large as to make this reading practically valueless.

There are many other meters of the differential producing type, most of which are modifications of Venturi tubes and orifice plates. Among these are flow nozzles and insert Venturi tubes. The orifice plate, although usually manufactured with a concentric bore, is also available in eccentric and segmental forms for liquids with moderate amounts of suspended solids, such as primary settling tank effluent. The Pitot tube is often a good compromise between cost and accuracy for clear water or air and gas.

A second group of primary flow measuring elements, other than the differential producers, are the positive displacement meters. These units, in general, have a high accuracy, low pressure loss, and great rangeability. They are, however, very expensive, especially in the larger sizes. Neither these units nor open channel measuring devices, such as Parshall flumes, weirs, etc., are discussed in this paper. A summary of several features of the common primary flow measuring elements is given in Table II.

TABLE II.—Comparison of Characteristics of Common Primary Flow Measuring Elements

Unit	First Cost	Pressure Loss	Accuracy	Use with Susp. Sol.
(*a*) Closed Conduits				
Venturi	Poor	Good	Excellent	Excellent
Orifice	Excellent	Poor	Excellent	Fair-Poor
Insert Venturi	Fair	Fair	Excellent	Good
Flow nozzle	Fair	Fair-Poor	Excellent	Fair
Pitot tube	Excellent	Excellent	Fair-Poor	Not acceptable
Positive disp.	Poor	Excellent	Excellent	Poor
(*b*) Open Conduits				
Parshall flume	Poor	Good	Fair	Fair
Weir	Excellent	Poor	Poor	Fair

The common type of secondary instrument used in conjunction with differential-producing meters is the mercury manometer flow meter. This instrument consists, basically, of two mercury wells connected with a U-tube. A float in one of the wells is connected through suitable linkages to an indicating pointer. As the differential produced by the orifice plate or Venturi tube varies, the levels in the mercury wells change to balance the new differential. The corresponding vertical movement of the float positions the indicating pointer in the flowmeter. The indicating scale is usually calibrated to read directly in flow units, or it can be a 0-to-10 scale and have a suitable multiplier.

From the description of this instrument, it should be apparent that the float movement is directly proportional to the differential and is, therefore, proportional to the square of the flow. In some cases this feature is undesirable, especially for wide flow ranges, as the first portion of the indicating scale will be very compact and the high end of the flow scale will be extremely expanded. This objection can be overcome by tapering the walls of one of the mercury wells in such a manner that the mercury displacement to balance various differentials causes a float movement proportional to the square root of the differential. This allows the flow scale to be graduated uniformly, giving equal readibility over all parts of the scale.

A new type of secondary instrument is the force balance, or null-balance instrument. This type of unit does not actually measure the differential, but rather it measures the force which is necessary to balance the differential, and keep the system in equilibrium. It can be likened to the familiar analytical balance, with which an unknown weight is determined by adding the necessary known weights to exactly balance the scale. Advantages of the force balance type of instrument over the mercury manometer are: (a) they are usually much smaller in size, (b) the range can be changed more readily, and (c) they are less expensive. They are generally regarded to be as accurate as the mercury manometer type, although they cannot be checked at zero differential as readily. The force balance instrument is not an indicating instrument and must be used as a transmitter in conjunction with an indicating receiver.

Measurement of Liquid Level

Measurement methods for liquid level are generally of two types: (a) direct measurement by means of a float, and (b) indirect by means of a

pressure sensing element whose elevation is known.

The float method is obviously the simplest and many adaptations are seen in sewage plants. Float units are currently available which will act as a pneumatic transmitter for remote indication of the liquid level.

One of the most common elements for which the liquid level is desired, however, is not well adapted to measurement by float. This is the separate sludge digester. Scum conditions at the liquid surface and the general viscous nature of sludge preclude using a float inside the tank and external level wells purged with effluent are usually not completely satisfactory.

For such conditions the best method appears to be a properly designed air or water purge system using a pressure sensing element. A typical water purge system would consist of a diaphragm box with the upper side of the diaphragm, the air side, connected through small copper tubing to a pressure indicator, and the lower side of the diaphragm connected to the tank to be measured. Water purged through the lower side of the diaphragm into the tank keeps the tank connection open and reflects the liquid pressure head through the diaphragm to the pressure indicator. This pressure or liquid level indicator would normally be a bellows-actuated unit with a scale reading in feet of elevation referred to some convenient datum. If gas is to be stored under pressure in the digester, a correction should be subtracted for the average gas pressure. The indicating unit may easily be equipped with adjustable high- and low-level alarms. A high-level alarm would be of value to prevent overflowing of a tank. A low-level alarm is of particular value where mechanical mixing is employed, so that a mixer will not be damaged by operating without adequate submergence. In fact, the mixer control could readily be interlocked with the low-level alarm.

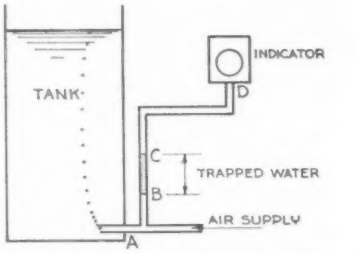

FIGURE 1.—Trapped water in indicator line gives erroneous reading on air purge system.

An air purge system operates on the same general principles as the water purge system. A small supply of air is bubbled into the tank and the pressure required to overcome the liquid head in the tank is fed to an indicator of the type previously described. One important precaution should be observed: the line leading to the tank should be carried to a point above the water surface and then connected into the tank at the proper elevation. If the indicating instrument is to be mounted at an elevation below the water surface, this involves looping the purge line to a point above the water surface. The purpose of this precaution is to avoid trapping a column of liquid in the line leading to the instrument, for the instrument will then read in error by the height of such column.

This is apparent from Figure 1. The pressures at A and B represent

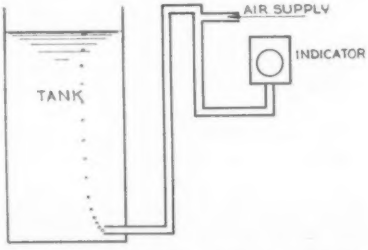

FIGURE 2.—Air purge system properly looped above liquid surface.

the true pressure head of the tank. However, the pressures at C and D are less than this true head by the amount of the head of the liquid Column BC. The correct method for this installation is shown in Figure 2.

Measurement of Temperature

The common methods of measuring temperature are based on three properties: (a) fluid expansion, (b) change in electrical resistance, and (c) generation of electrical potential. For industrial uses, the most important method is the last.

The primary device for the electrical potential method is the thermocouple, which generates a voltage so small that it must be measured by a millivoltmeter or a potentiometer. The disadvantage of the millivoltmeter is that the resistance of the thermocouple leads is introduced as a source of error. Using a potentiometer, when the circuit is balanced no current flows through the thermocouple leads and the effect of their resistance is eliminated.

All ranges of temperatures normally encountered in a sewage treatment plant can be measured with the proper thermocouple materials. The base metal couples such as copper-constantan, iron-constantan, and chromel-alumel will suffice for sewage, digester, and sludge drying furnace temperatures. The expensive noble metal couples, such as platinum and platinum-rhodium, which will measure temperatures as high as 3,000° F., are not required for sewage treatment plants.

One of the major advantages of a thermocouple and potentiometer system over the other types of temperature measuring devices is the ease with which the potentiometer can indicate or record several temperatures. A complete battery of digester tanks, or several points through a drying furnace system, can have thermocouples connected to a single instrument. The instrument can record the temperatures on a strip chart by means of a printing wheel and automatic selector switch, or it can be an indicating instrument with a group of push buttons.

TABLE III.—Comparative Ranges of Temperature Measuring Devices

Temperature Measuring Element	Max. Temp. (°F.)
Fluid filled	1,000
Resistance thermometer, base metal	300
Resistance thermometer, noble metal	1,800
Thermocouple, base metal	2,000
Thermocouple, noble metal	3,000
Optical pyrometer	5,000

The recording instrument will print a color-coded and numbered point on the chart for each temperature to be recorded, normally not more than twelve. The printing speed and chart speed are adjustable, depending on the record required. The indicating instrument is equipped with push buttons or key switches, enabling the operator to select any of as many as 24 temperature points.

The multiple systems described, as they require only one potentiometer circuit for as many as 24 remote thermocouples, are extremely economical. In addition, valuable instrument control board space is conserved.

A brief comparison of the temperature ranges of the various types of temperature measuring devices is given in Table III.

Remote Transmission

The remote transmission of flow, liquid level, and temperature readings is an important factor in sewage treatment plants to enable the operator to follow the various processes from a central point. This practice, of course, should not be carried to an extreme, but because of the resulting savings in labor costs there has been an increasing trend towards the centralized control room. When automatic con-

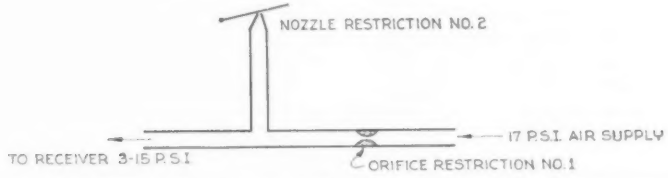

FIGURE 3.—Basic elements of pneumatic transmission system.

trol is considered, remote transmission is almost always a necessary factor.

Remote transmission of temperature and liquid level measurements, if the primary elements are those most completely described previously, will not normally be a problem. As pointed out, because of the null-current characteristic of the potentiometer circuit, thermocouple leads may be run considerable distances without difficulty.

In the cases of liquid level measuring systems described, with some sacrifice in speed of response, the tubing from the measuring point to the instrument location can be as long as necessary.

For flow measurements, however, with a primary element of the differential producer type, it is unwise to attempt to extend the pressure piping to a mercury manometer type flowmeter a distance greater than about 75 ft. This limitation will usually require that important flow readings be relayed by a transmitter.

The transmission system used may be either electric or pneumatic. Pneumatic transmission is a newer development and the writer is particularly inclined towards its use in sewage plants for the following reasons:

1. It can be used where explosive conditions would make electrical transmission hazardous.
2. It can be used where electric current is not readily available.
3. Its operating parts are less likely to be injured by the corrosive atmosphere of sewage treatment plants.
4. The interconnecting small-diameter copper tubing may be run exposed in pipe access spaces, instead of in electric conduit.
5. Maintenance of both the transmitter and receiver is generally simpler for pneumatic units.

A detailed description of pneumatic transmission components would be out of place in this work. The details of the mechanisms employed vary among the various instrument companies. However, the basic principle in each case is the same. This common principle consists of a double restriction and a flapper (Figure 3).

A regulated air supply, normally at 17 p.s.i., is admitted through restriction No. 1 and exhausted to atmosphere through restriction No. 2. The pressure in the system thus is controlled by the amount of air escaping through restriction No. 2, which in turn depends upon the position of the flapper. By connecting the flapper to the indicating pointer of the flowmeter, through proper linkages, the output air pressure, normally 3 to 15 p.s.i., is proportional to the indicating pointer position. The line to the receiving unit is dead-ended and the receiving instrument is then essentially a simple pressure gauge with a range of 3 to 15 p.s.i. and an indicating scale matching the transmitter.

The connection between the transmitter and the receiver is usually made with ¼-in. O.D. copper tubing and may be made sufficiently long to cover any application in a sewage treatment plant. The writer has personal knowledge of one installation involving 2,000 ft. of connecting tubing and another involving approximately 6,000 ft. In

both instances, however, changes in flow rates are not rapid and the resulting lag time in transmission is of no consequence. Where automatic flow control is involved, the transmission distance should be kept as short as possible, with a maximum distance in the order of 500 ft.

This method of remote transmission is, of course, not limited to flow readings. Temperature, liquid level, pH, pressure, or any other variable may be transmitted in this manner once it has been measured, for the method is merely concerned with repeating an indicating pointer position. It should also be pointed out that any number of receivers can be connected to one transmitter, with the only governing factor being the effect of the volume of tubing involved upon transmission lag time.

Automatic Control

Although the measurement and remote transmission of flow, liquid level, and temperature can certainly and justifiably be regarded as ends in themselves, they are also the primary steps towards automatic control. Therefore, brief mention of some of the consequences of automatic control appears in order.

There is no theoretical reason why manual or human control cannot be as successful as automatic control. Indeed, there are reasons why it can surpass automatic control. An operator can judge for himself the effect of a given deviation from the control point and perhaps wait to see if the deviation is permanent or momentary before attempting a correction. The basis for his final correction could be based on past experience combined with knowledge of future requirements, information which would not be available to a controlling instrument. Despite these theoretical considerations, however, interrelated systems requiring control can easily exceed the comprehension and physical ability of men to operate by manual means. Sooner or later a human operator will fail to make a necessary correction, resulting in an upset of the system.

The advantage of the automatic control instrument is that it will react in a predetermined and logical manner to any deviation from a desired value. It can be equipped with the necessary mechanisms to limit variations of the controlled medium to any reasonable degree.

The basic types of controllers are as follows:

1. On-off control.
2. Proportional control.
3. Proportional and floating control.

The terminology given corresponds to definitions given by the A.S.M.E. Committee on Industrial Instruments and Regulators. Among the instrument manufacturers and engineers, the third listed function is commonly called proportional plus automatic reset control. In addition to the controlling actions listed, further functions include the derivative actions, developments which are designed to limit deviations to the smallest possible degree.

Although detailed descriptions of the control mechanisms of the three control methods listed are beyond the scope of this paper, each is briefly described with an illustration of its effect on the control valve and the process variable. In all cases, for simplicity, a pneumatic controller is assumed.

On-Off Control

The on-off control is the simplest of the controller actions and is, as the term implies, a two-position control. Normally, the valve must either be in the full open or full closed position, although any two positions can be chosen.

Figure 4 shows the valve response to an on-off controller corresponding to measurement changes shown. For

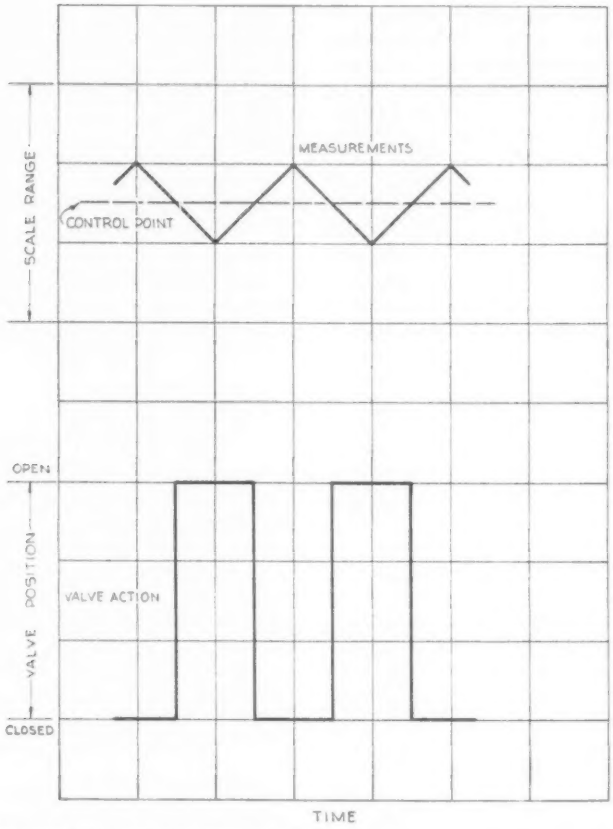

FIGURE 4.—Valve position in relation to measurement; on-off control.

all values of the measurement which are above the control point the valve is at one position; for all values below the control point the valve is at another position. There is no mid-position. Therefore, the controlling action is inherently a cycling action, with the measurement overshooting the control point. The amount of overshooting, the amplitude of the cycle, is a function of the lags involved.

This type of control is not necessarily unsatisfactory. Actually, when applied to processes such as the temperature control of a large mass, the amplitude of the cycle may be so small that the record appears as almost a straight line. A familiar example of this type of control is the home thermostat, which fully opens the fuel valve when the temperature is below the control point and fully closes the valve when the temperature has reached the control point.

Proportional Control

There are many processes which cannot be successfully operated with the cycling of the on-off controller. The first refinement consisted of a mechanism to cause a valve action proportional to the deviation from the control

point. Proportional control action is shown by Figure 5. Whenever the measurement deviates from the control point, the valve response is proportional to this deviation. The valve position always bears a fixed (but adjustable) relation to the deviation of the measurement from the control point. This action results in an adjustable proportional band or throttling range. A proportional band of 100 per cent is one in which a full-scale measurement change is required to produce full travel of the valve. With such a proportional band a 10 per cent change of measurement would produce a valve response of 10 per cent of its full travel.

It will be seen, then, that a proportional controller with a 0 per cent proportional band is merely an on-off controller and will act as shown in Figure 4. The proportional band of most proportional controllers may be adjusted from 0 per cent to as high as 600 per cent, depending on the type of control desired.

It is important to realize the limitations of straight proportional control. If the hydraulic conditions change, which would require a new valve position to return the measurement to

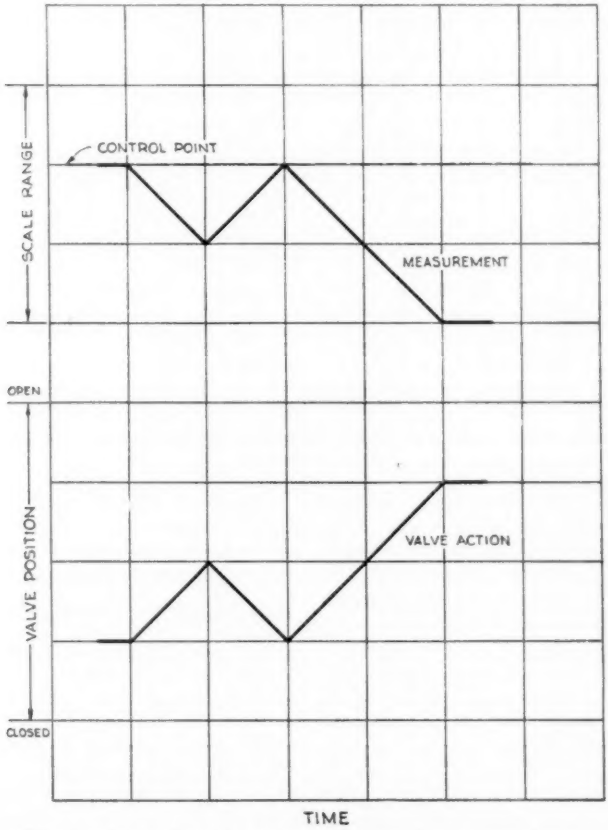

FIGURE 5.—Valve position in relation to measurement; proportional control.

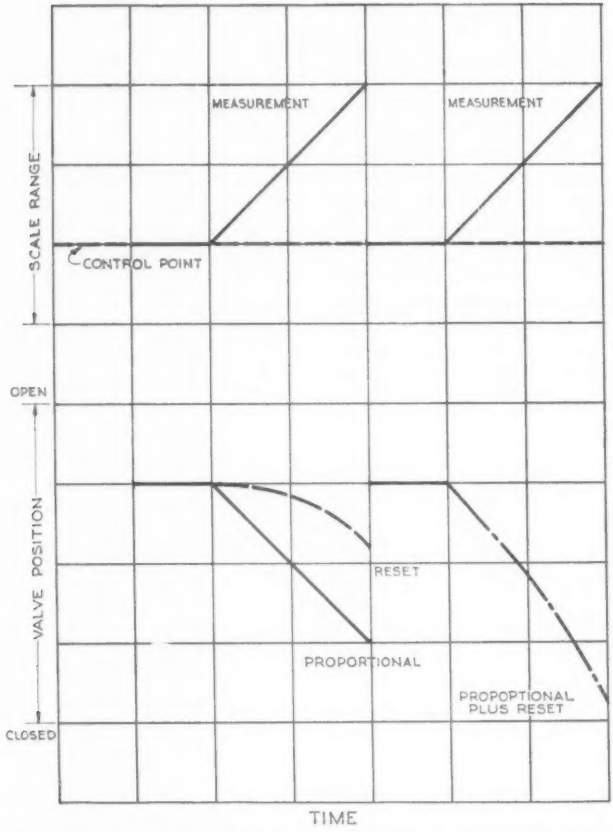

FIGURE 6.—Valve position in relation to measurement; proportional plus automatic reset control.

the control point, the proportional controller cannot re-establish the exact original flow. Therefore, the proportional band must be set narrow enough to produce sufficient valve movements to keep the measurement within an acceptable range. This deviation from the control point is called "offset" or "droop." The danger of trying to minimize droop with a proportional controller by setting too small a proportional band is that the controller may start to act as an on-off controller and establish a continuous cycle as shown in Figure 4.

Therefore, it is apparent that for conditions requiring a more exact control of the measurement, an additional control mechanism is required.

Proportional and Floating Control

The proportional and floating controller, commonly called "proportional plus automatic reset," was developed to overcome the inability of the proportional controller to return the measurement to the control point upon a change in hydraulic conditions. The floating (or reset) action acts to eliminate droop or offset of the measure-

ment by producing a valve movement *rate* which is proportional to the measurement deviation.

As shown in Figure 6, the proportional action has the greatest initial effect on the valve. However, if the upset is caused by a change in load or other variables, the reset action will continue to act in the manner shown until a new valve position is established which will return the measurement to the original control point. It should be noted that, as shown in Figure 5, the proportional action now has no effect and the new valve position is completely the result of the reset action. It is also worthwhile to repeat that the largest initial correction is due to the proportional action. Thus, while a controller with reset action but without proportional action would return the measurement to the control point, the process would tend to overshoot by a large amount.

With this type of controller it is possible to adjust the proportional band so large that the controller is essentially a floating or reset controller. Or the reset speed may be adjusted so slow that the controller is a simple proportional controller. Because of these facts, it is wise to specify a proportional plus reset controller for all controlling problems where a throttling control is required. The extra cost of the reset action would not exceed about 5 per cent of the controller cost and would be available if required.

Control Valves

The final objective of almost every automatic controller is to produce a change in valve position which will maintain the measurement at the proper value. The control valve should actually be considered as a part of the controller.

The method by which a pneumatic controller alters a valve position is by varying the controller output air pressure to the valve operator. For small valves, the operator consists of a diaphragm connected to the sliding valve stem. A spring force tends to move the valve stem and diaphragm in one direction and is opposed by the controller output air pressure acting over the area of the diaphragm. For larger valves the operator is a cylinder and piston with a valve positioner which acts as a servo mechanism. The controller output is sent to the valve positioner, which in turn admits high-pressure air to one side of the piston to position the control valve in accordance with the controller output pressure.

There are certain desirable characteristics to be looked for in a control valve. From the previous descriptions of the proportional plus reset controller, it was determined that a linear relation between the change in measurement and valve positioning force was produced by the proportional action and a linear relation between the rate of measurement change and valve positioning force was produced by the reset action. The ideal control valve would be one in which there is a linear relation between equal increments of valve movement and the percentage change in flow rate. This characteristic results in favorable control sensitivity at both high and low rates of flow.

Consider, for example, a control valve which moves from its 80 per cent open position to 90 per cent open, and causes a 50 per cent increase in flow rate. It would be desirable for a valve position change from the 20 per cent open position to 30 per cent open to also cause a 50 per cent increase in rate of flow.

Control valves are manufactured which correspond to this requirement over a large part of their travel. They are called "equal-percentage characteristic" valves. A curve for such a valve is shown in Figure 7 labelled "characterized V-port valve." It should be noted that when valve lift is plotted against per cent of maximum

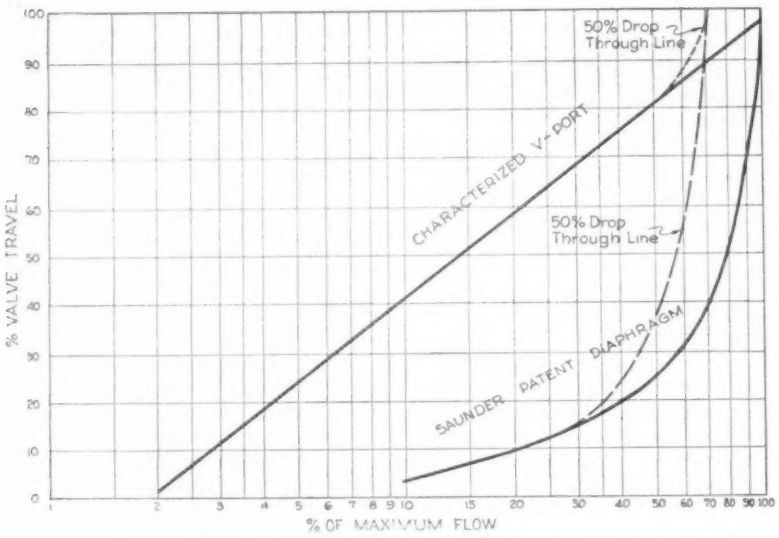

FIGURE 7.—Flow *vs.* lift characteristic for characterized V-port and Saunders Patent diaphragm valves.

flow on semi-log paper, a straight line results. The particular valve shown has a straightline characteristic from about 2 per cent to about 100 per cent of its maximum flow and, therefore, has a rangeability of 50 to 1 (that is, it can properly control flow rates over a 50 to 1 variation).

A factor which tends to alter this desirable condition is the effect of pressure drop through the piping system. If practically all of the friction loss in the system is incurred at the valve, the characteristic would be essentially the straight line shown. In actual practice, a portion of the total drop is used up in the pipe and fittings, varying with the velocity of flow. This effect reduces the rangeability of the valve and results in the dotted curve shown at the top of Figure 7. This portion of the curve is less desirable, as equal percentages of valve movement no longer produce equal percentage increases of total flow. The condition shown is for 50 per cent of the total system pressure loss with a full open valve being lost through the piping. For larger percentages lost in the piping, a greater deviation would result; however, the equal-percentage characteristic valve resists this distortion better than any other valve.

Unfortunately for sewage treatment plants, this type of valve cannot be used for flows with suspended solids. The design of the inner valve is such that the flow passages would rapidly clog under such conditions. This type of valve can be used for gas, air, clear water, oil, etc., but for sewage and sewage sludges it is not suitable.

A valve specifically designed and developed for use with sludges and slurries is the "Saunders Patent" diaphragm valve. This valve is essentially a simple pinch clamp, which offers an almost straight-through flow path. Closure is effected by forcing a flexible reinforced rubber diaphragm against a weir-like seat. As the diaphragm seals off the flowing fluid from the

TABLE IV.—Diaphragm Valve Constants [1]

Valve size (in.)	Per Cent of Valve Lift									
	10	20	30	40	50	60	70	80	90	100
2½	18[3]	42	57	83	99	103	107	109	112	115
3	30[2]	60	97	125	157	187	192	196	206	209
4	150	180	215	255	290	320	340	346	346	346

[1] Excerpted from Hills-McCanna Co. Catalog No. V-50.
[2] Extrapolated by author.

working parts of the valve, no packing is required.

The diaphragm may be furnished in a variety of materials. Natural rubber is the least expensive and the author has found it to be satisfactory for both raw and digested sewage sludges. For other fluids, Neoprene, Hycar, Teflon, Kel-F, and other diaphragm materials can be furnished. Where corrosive conditions are such that a metal valve body would be attacked (chlorine solutions, ferric chloride solutions, etc.) the valve body itself may be rubber lined.

The flow *vs.* lift characteristic of a typical "Saunders Patent" diaphragm valve is shown in Figure 7. It is at once apparent that there is a marked difference between this valve and the V-port valve. The straightline or equal-percentage portion of the diaphragm valve could perhaps be assumed to be from 5 per cent of maximum flow to 25 per cent of maximum flow, which results in a rangeability of 5 to 1, compared to the 50 to 1 for the V-port valve.

This does not necessarily mean that the diaphragm valve is not satisfactory for control purposes. Rather, it means that the valve size must be carefully selected with respect to the flow range desired, the total pressure loss in the piping system, and the percentage of this pressure loss which can be incurred at the valve. In this regard, it should be noted, as shown in Figure 7, that the characteristic for the diaphragm valve is very considerably distorted with 50 per cent of the pressure loss occurring in the piping, which tends to reduce the available rangeability. The distortion resulting from greater percentages of loss in the piping would be correspondingly greater. Also, the characteristic curve shown in Figure 7 is for a 6-in. "Saunders Patent" diaphragm valve. Other sizes have characteristics which vary slightly.

Tables IV and V illustrate a typical diaphragm valve selection calculation. The relation between the constants shown in Table IV and flow and pres-

TABLE V.

Flow (g.p.m.)	Total Head (ft.)	Static Head (ft.)	Friction Head (ft.)			Valve Constant Req'd[1]	Valve Lift (%)[2]		
			Avail.	Piping	Valve		2½-in.	3-in.	4-in.
200	80	15	65	3	62	39	18	12	<10
400	72	15	57	11	46	89	45	27	<10
600[3]	77	15	62	23	39	146	[4]	45	10

[1] Specific gravity assumed 1.0.
[2] For valve size shown.
[3] Two pumps operating.
[4] Maximum constant is 115; system is limited to about 500 g.p.m. with full open valve.

sure drop is given by the equation:

$$\text{Constant} = \frac{Q\ (\text{g.p.m.}) \times \sqrt{\text{Sp. Gr.}}}{\sqrt{\text{Pressure Drop (p.s.i.)}}}$$

These values allow the determination of valve positions as shown in Table V, the hydraulic calculations for which were based on an equivalent length of 1,000 ft. of 8-in. pipe with a Hazen-Williams C of 70. Centrifugal pumps were assumed to be the source of pressure with head-capacity characteristics resulting in the total heads shown.

From the results shown in Table V, the proper valve for the purpose is seen to be a 3-in. valve. This valve will control the flow over the best portion of its valve characteristic curve shown in Figure 7.

A consideration of the results had either a 2½-in. or a 4-in. valve been selected is of interest. As shown, the 4-in. valve would never open more than 10 per cent of its total lift. Undesirable and probably cycling control would result. Selection of the 2½-in. valve would allow good control at 200 and 400 g.p.m., but with the valve full open the total flow would be slightly over 500 g.p.m. instead of the 600 g.p.m. desired.

From the results indicated in Table V, it should also be apparent that the valve size required had no fixed relation to the pipe size and must be determined from the hydraulic characteristics of the system.

Conclusion

An attempt has been made to present modern instrumentation as a tool for sewage treatment. Like any tool, it must be understood to be used effectively, but the consequent rewards in more efficient sewage treatment are large.

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PROPOSED SEWAGE WORKS IMPROVEMENTS AT TOLEDO, OHIO *

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The first move toward treatment of sewage in Toledo, Ohio, dates back to 1913, when the State Department of Health investigated conditions in Ten Mile Creek, which drains the north and west sections of the city, and as a result of the findings ordered the city to build intercepting sewers and treatment works. In 1916 the city's Engineering Division made a study which led to a bond issue sufficient to pay for the construction of two main interceptors and a pumping station. One interceptor paralleled Ten Mile Creek; the other, the west bank of the Maumee River and Swan Creek. These works were completed in 1922 and the Bay View Park pumping station started operation the same year, discharging raw sewage from most of the west side of the city directly to the river at a point near Maumee Bay. With the exception of some minor extensions of the West Side interceptor, nothing further was done until in 1926 a bond issue was voted to continue the work.

Between 1928 and 1931 the West Side interceptor was further extended, and the East Side interceptor, the East Side pumping station, the Maumee River tunnel, and the present sewage treatment plant were built. Operation of the plant started in 1932, but due to lack of funds the East Side pumping station and the tunnel under the river to the treatment plant were not placed in operation until July of 1933. This system, with a few interceptor extensions, has been in operation continuously since that time.

Plant Units

The present treatment plant is located on an island separated by a narrow channel from the west shore of the river and Bay View Park. The Bay View Park pumping station is also at this location and serves to deliver sewage from the West Side interceptor system into the plant. Sewage from the East Side pumping station is delivered to the plant through the 3,000-ft. tunnel, under the Maumee River.

The plant units consist of two mechanically cleaned bar screens, two detritors, eight primary settling tanks, and eight digesters. Digested sludge is pumped to glass-covered drying beds located about 1 mi. from the treatment plant, or to waste in a swamp area adjacent to the beds. The plant equipment includes chlorination facilities for pre- or post-chlorination. Digester gas is utilized for heating the digesters and buildings and as fuel for two gas engines, one driving a main sewage pump and the other connected to a generator which furnishes power for treatment plant operation.

During the early years of World War II considerable and increasing quantities of oil and greases gave rise to some operating difficulties. Preaeration and grease removal facilities were designed in 1944, but were never built due to lack of financing. These facilities may be included in the present improvement program if further study shows them to be desirable.

* Presented at 26th Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Toledo, Ohio; May 21–23, 1952.

Effect of River Flow

A study of the need for secondary treatment was undertaken in 1945. One of the first points to be determined was whether the Maumee River discharge, carrying treatment plant effluent, has any effect on water quality at the Toledo water supply intake, which is located in Lake Erie about 13 mi. east of the sewage treatment plant and 2 mi. offshore.

In connection with this study, movement of water through Maumee Bay from the river to the lake was shown to be affected, both as to rate and direction, by wind movement. Under the influence of winds, the recorded water levels at the river mouth have varied from 6.0 ft. above to 7.5 ft. below mean lake level. During high winds from the north and east, the net movement of water is often from the lake to the bay and river, even when the river discharge is relatively high. At

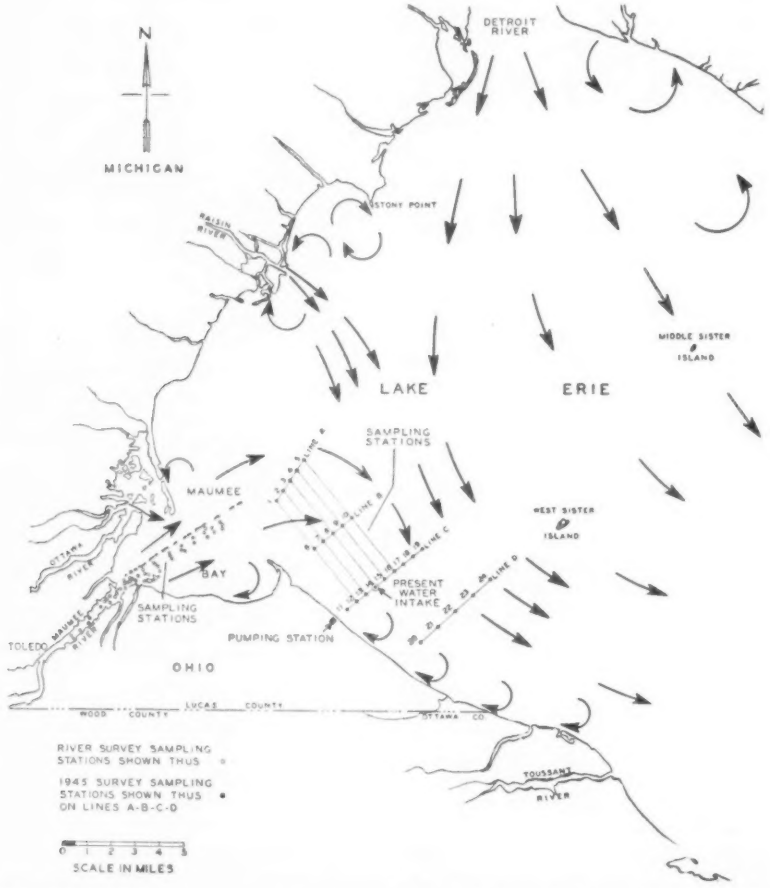

FIGURE 1.—General currents in western end of Lake Erie and location of river and lake sampling points.

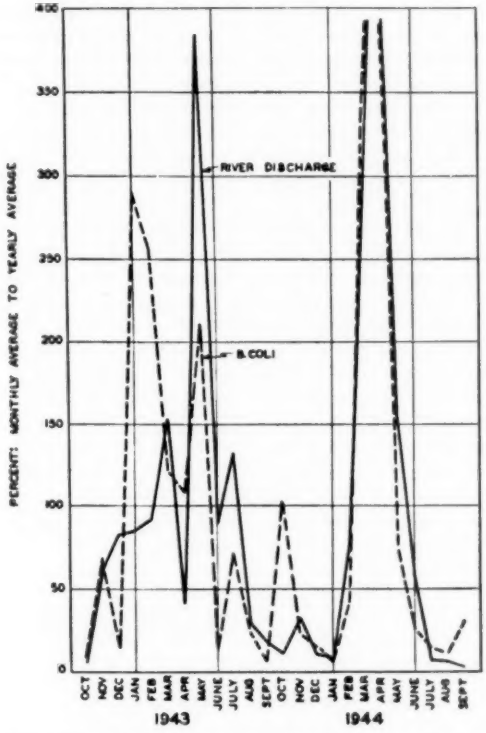

FIGURE 2.—Relation between *B. coli* at Toledo water intake and Maumee River discharge.

other times, under the influence of westerly winds, the outflow from the bay is much greater than the river discharge. While this movement in the bay undoubtedly provides considerable dilution, it also tends to discharge any pollution present in large slugs.

Water movement in the lake likewise is influenced by winds and by differences in barometric pressure, but in a more general way seems to be governed at the west end of the lake by discharge of the Detroit River. This discharge, averaging more than 180,000 cu. ft. per sec., is directed toward the south shore. Effluent of the tributary streams, principally the Raisin and the Maumee in the west end of the lake, tend to be diverted southward to stream along the south lake shore. The general direction of the currents can be estimated as shown in Figure 1, which also shows the location of sampling stations used regularly in river surveys by the treatment plant staff and of sampling stations used in a survey in connection with the 1945 report.

Several factors were investigated to determine whether river discharge has any effect on water quality at the intake. Plotting monthly average *B. coli* against monthly average river discharge, expressed as a percentage of the yearly average, indicated that *B. coli* counts at the intake were affected, particularly by high relative rates of discharge. Turbidities were similarly

affected, both *B. coli* counts and turbidity observations being highest when the river discharge was at its maximum. Chloride content of the water is variable, but tends to be higher at low river discharge rates when dilution is at a minimum. The lowest chloride content is observed when river discharge, and consequently dilution, is at a maximum. Figure 2 shows the effect of river discharge on *B. coli*, plotted for the period from October, 1942, to September, 1944. Figure 3 shows the relationship between river flow and chlorides with the values plotted as running averages for periods ending at the times indicated, for a total period of approximately two years.

The co-relation is not in proportion, since in any case it would be affected by variable currents set up by wind movement. It is, however, generally consistent and unmistakable.

During the course of the study, numbered sampling stations were established by setting buoys in the lake along four lines (see Figure 1) indicated as lines A, B, C, and D. Water samples were collected from the stations in lines A, B, and C for a short period in November and December, 1944. These stations were re-established in the spring of 1945 and line D was added. Samples were collected from all stations during May and June, 1945, generally at two-day intervals.

The evidence thus collected could not in itself be considered conclusive, as the period covered was too short. Therefore, no attempt was made to relate the observations to river discharge or wind direction and force. It was indicative, however, and helped to support the conclusions. Plotting the results of analyses of turbidity, color, hardness, and 37° agar plate counts

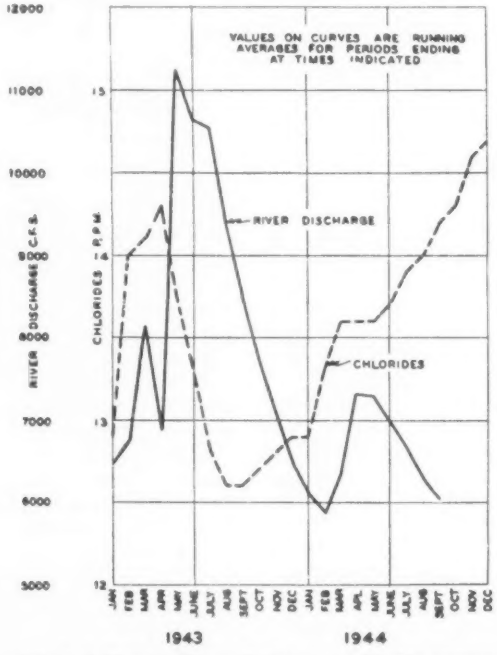

FIGURE 3.—Effect of Maumee River discharge on chloride content of Lake Erie at water intake.

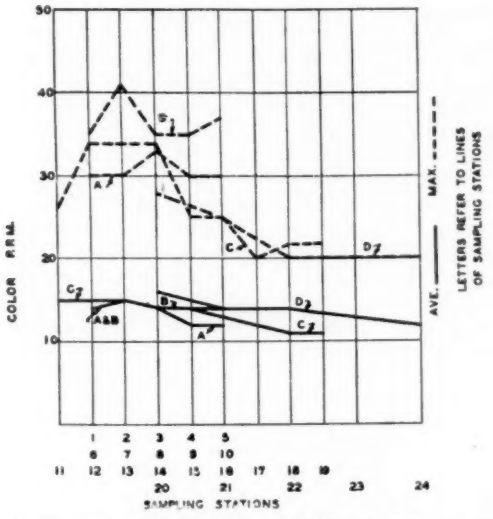

FIGURE 4.—Average and maximum color of Lake Erie water at sampling points.

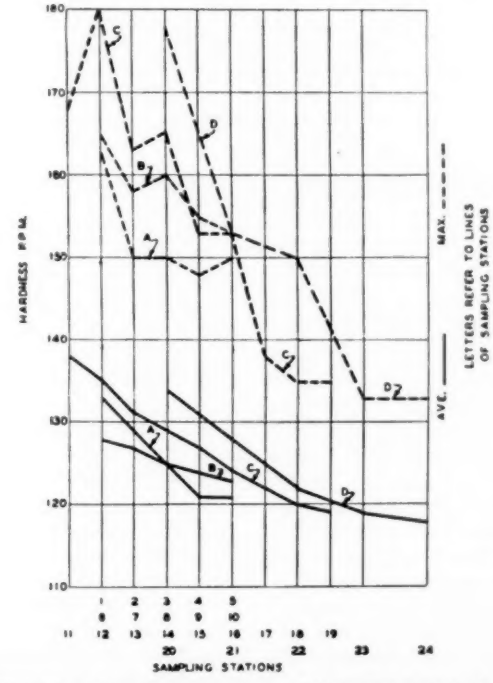

FIGURE 5.—Average and maximum hardness of Lake Erie water at sampling points.

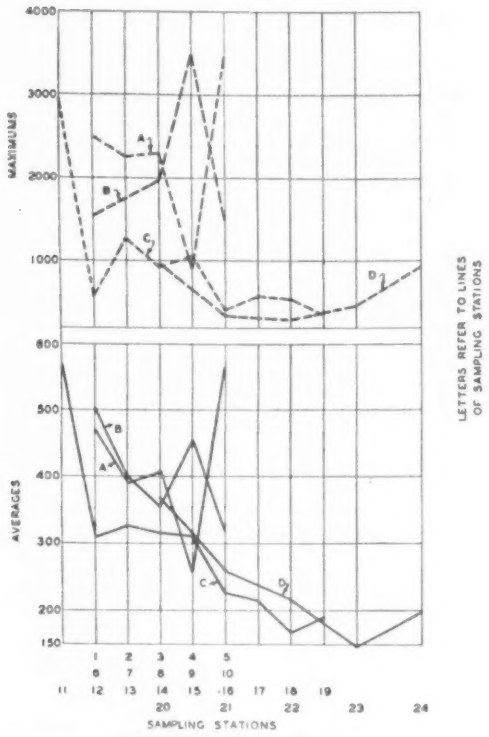

FIGURE 6.—Average and maximum 37° C. agar plate counts of Lake Erie water at sampling points.

against location in reference to the lake shore shows that the water quality improves, up to a point, as the distance from shore increases. The best evidence from these observations indicating that the river water tends to stream along the lake shore is shown by the hardness observations. The river water is harder than the lake water except during times of maximum river discharge. The examinations showed that hardness was consistently higher both as to average and maximum figures near the shore, and diminished as the distance from shore increased. Figures 4, 5, and 6 show average and maximum values observed for color, hardness, and 37° agar plate counts, respectively.

Need for Higher Treatment

The conclusions reached were that the relationship of sewage treatment to quality of raw water at the Toledo waterworks intake differs only in degree from the condition that would prevail if the intake were located on a river downstream from the city. Time of flow from river mouth to intake probably varies from a matter of hours to a number of days, and there is undoubtedly a large though variable factor of dilution. The evidence indicates, however, that pollution contained in the Maumee River discharge passes through the vicinity of the water intake before losing identity in the waters of the lake.

To the evident necessity thus indicated for protecting the water supply by adequate treatment, should also be added that of protecting bathing beaches along the lake shore and reducing the load of fine silt now being deposited in the bay and lake, fouling beaches and filling channels.

Further need for a higher degree of treatment is evidenced by dissolved oxygen deficiencies frequently observed in the vicinity of the treatment plant outfall and for several miles downstream during times of low stream flow. The lowest observation prior to 1945 was 0.8 p.p.m., and many readings were between 1 and 2 p.p.m. The effects of oxygen deficiency probably are important only as to the bay area, because dilution and reaeration will correct the condition before the flow has travelled very far into the lake. However, for the protection of the lower river and bay area, further reduction of oxygen demand is a real necessity.

The factors pointing to need for higher degree of treatment also determined the necessary functions to be served by sewage treatment additions. They can be briefly listed as follows:

1. High degree removal of suspended solids.
2. Effective and continuous sterilization.
3. Reduction of biochemical oxygen demand.

Maximum reductions reasonably attainable in conventional sewage treatment facilities are indicated to be required, both as to suspended solids and B.O.D.

Secondary Treatment Studies

Studies were made accordingly to determine the best type of secondary treatment for the requirements and location. Lack of sufficient site space, high cost, and other factors ruled out the use of trickling filters, so that activated sludge was selected as the type of treatment to be provided.

Studies of capacity requirements showed an average flow from 1933 through 1940 of 33.3 m.g.d., with a maximum annual average of 34.1 m.g.d. in 1937. Starting in 1941, and reflecting increased industrial activity during the war period, the flow increased about 10 per cent, averaging 36.6 m.g.d. for the 4-year period ending December, 1944. The maximum year was 1943, when flow averaged 37.4 m.g.d.

Because the Toledo sewer system is practically all combined, the pattern of sewage flow varies over wide limits from wet to dry periods. During months of frequent rainfall, generally during the spring months, the sewage flow is consistently at higher levels than during the drier periods usually observed during late summer and fall. Analysis of the flow records over the 4-year period 1941 to 1944, inclusive, indicated that monthly average flow exceeded 40 m.g.d. during 27.1 per cent of the time, 44 m.g.d. 16.7 per cent of the time, and 45 m.g.d. 12.5 per cent of the time. Computations of sewage strength, as measured by total weight of B.O.D., showed that the peak could be expected at about 40 m.g.d., with a slow decrease to 45 m.g.d., and after that point the decrease was rapid. Capacity to be provided for the then existing flow was accordingly set at 45 m.g.d.

The reserve capacity to be provided for future increase turned out to be much too small. At about the same time these studies were being made, the Census Bureau released estimates of future trends in population. The forecast for Toledo was that the city probably would not share in postwar population increases expected in most industrial centers, and might even lose population. On the basis of that prognostication, the recommended reserve capacity was set at about 10 per cent as a prudent figure and the design basis at 50 m.g.d., although it was further recommended that financing be

arranged so that additional capacity could be provided readily if need should arise.

Everyone is familiar with what happened after the war. Both water consumption and sewage flow increased rapidly and by large amounts, in Toledo as well as practically everywhere else.

The actual increases in flow were far in excess of anything to be reasonably expected from a city with supposedly little prospect of postwar growth, as shown by the following:

Year	Average Flow (m.g.d.)
1945	38.3
1946	36.7
1947	46.3
1948	44.8
1949	46.5
1950	54.3
1951	53.9

The increase started in 1947, and at the end of five years totalled about 48 per cent over the average of the base period of 1941 to 1944, inclusive.

Plans were started in 1946 and completed in 1948 on the basis of design determined by the study of 1945. By that time the average flow had increased some 25 per cent over a two-year period. It was realized that the designed plant would be taxed to capacity if the sudden increase held up, but since the plans were to be laid on the shelf for future financing, it seemed logical to wait and see what the rapid flow increase would amount to before deciding how much more capacity should be provided.

Site Problems

An additional complication has recently been added concerning the site upon which the works are to be built. It was originally intended that secondary treatment units would be located adjacent to the primary plant on the northerly side, in space now occupied by a ship mooring basin. When planning was undertaken in 1946 this location was adopted, since a new, larger, and better mooring basin was then contemplated at another location. In the intervening years the proposed new mooring basin project has been abandoned so that there is considerable interest in retaining the present one. In addition, high costs of a retaining wall and hydraulic fill required to make the site available for a plant site are also important factors. Studies are accordingly in progress to determine the best available alternate site. Two areas were apparently available, one in the golf course adjacent to the small channel dividing the present site from Bay View Park, and the other on the river front immediately upstream from the present plant. The upstream site will probably be selected, as use of the park area would practically destroy the golf course.

Before plans can be revised to accommodate the change of site and increased capacity requirements, some re-study will be required as to the rate of sewage flow to be provided for, including reasonable reserve for future increase.

Problems of Existing Units

Other factors that will require some consideration include diminished effectiveness of the existing detritors, which is evidenced by carryover of quantities of fine sand to the digesters; decrease in suspended solids content of raw sewage; lower observed efficiency of solids removal by primary tanks; and, perhaps most important, an actual decrease in gas production. These factors have been in evidence during the past two years. As compared with the base period of 1941 to 1944, inclusive, the average of 1950–51 shows sewage volume 48 per cent greater and total weight of raw suspended solids 27 per cent greater, but total gas production 13 per cent less. Efficiency of suspended solids removal dropped from 56.6 per cent to 46.8 per cent so that this factor, plus the fact that volatile

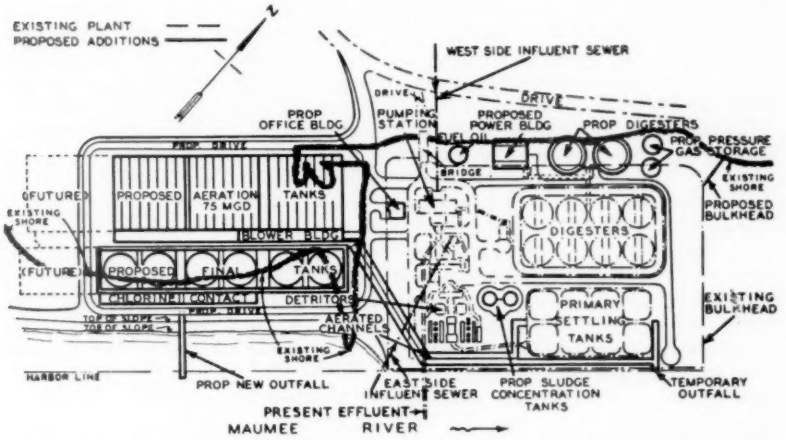

FIGURE 7.—Proposed layout for secondary treatment and other additions to Toledo, Ohio, sewage treatment plant.

solids percentages were also a little lower, accounts for some of the discrepancy in gas production, but not for all of it. Since sewage flows have increased at a far greater rate than contributing population, it is not unreasonable to expect a decrease in strength of sewage and, to some extent, of efficiency of sedimentation. However, the decrease observed in B.O.D. removals from an average of 41.1 per cent during the base period to 28.8 per cent during 1950–51, might indicate that the finely divided organic material that otherwise would be available for gas production is going out with the plant effluent.

As indicated previously, the 1948 plans contemplated adding activated sludge units to the present primary plant for secondary treatment. The existing plant was designed to provide plain sedimentation for an average flow of 80 m.g.d. to serve a population of 600,000. Hydraulic capacity of the plant, with the exception of the old outfall, is in excess of 200 m.g.d. When the original plant was designed about 25 years ago, it was considered to be adequate to provide sufficient primary treatment preceding future activated sludge units for an average flow of at least 100 m.g.d. When required plant capacity exceeds 100 m.g.d., it will be necessary in any case to provide both primary and secondary facilities in a new plant and new location. The proposed layout for the upstream site is shown in Figure 7.

New Unit Designs

The aeration tanks were designed as four-pass units of 12.5 m.g.d. each. By using the hollow upper portion of the flared walls as influent channels, incoming sewage can be distributed incrementally over as much as 50 per cent of the length of the tanks, or can be admitted entirely at the upper end as desired. Air will be applied through swing diffusers.

The final tanks were also designed to have a capacity of 12.5 m.g.d. each. In effect, one aeration tank and one final tank form a unit of capacity. Interconnection is through common influent channels so that any tank can be taken out of service without affecting the operability of any other.

All influent channels, starting at the primary tank are of large size to minimize hydraulic losses, and are

aerated to avoid deposition of solids.

Final effluent will be chlorinated, and retained for about 20 min. in a contact chamber or channel before discharge to the river.

The pipe gallery between the aeration and final tanks serves as the blower building. Six centrifugal blowers, each with 9,000 c.f.m. capacity, were contemplated in the 1948 design, with space for four more similar units, which will be ample for all future requirements. Return and excess sludge pumps are also located in the same area, with ample space for expansion. Meter registers and controls will be located in a control center near the blower room.

The eight existing digesters were designed to provide for a population of 600,000. They are all of the fixed-cover type with stirring mechanisms and scum breaker arms. The present program includes provision for continuous recirculation of digester contents, thus making the total present capacity available for digestion. Two new tanks without mechanisms, but with gas holder covers, will be provided for sludge and gas storage. It is expected that the present practice of disposing of digested sludge as fill in a marsh area, and as fertilizer, can be continued for another 10 or 15 years so that there are no present plans for sludge drying or incineration facilities.

It is planned to include dual-fuel engines driving generators to provide power for operation of the treatment plant and the Bay View Park pumping station. As planned, the power station will include four engines of about 1,200 hp. each, with total generator capacity of about 3,500 kw. At the time plans were prepared in 1947 and 1948, the gas available from digestion was computed to be about 79 per cent of that required to generate the whole power requirement. In view of the observed decrease in gas production, particularly during the past two years, it will be necessary to make some re-study of gas utilization before actual construction is undertaken.

In 1951, the Toledo voters authorized a $10,000,000 bond issue to finance sewage treatment improvements and at the same time voted $7,500,000 for waterworks extensions. Both projects required considerable increases in existing rate schedules. The City Council has given priority to the water project and has deferred construction of sewage treatment additions for two to three years, during which time it is expected that the new site will be acquired and necessary plan revisions will be completed.

A QUARTER CENTURY OF SEWAGE TREATMENT IN THE CENTRAL STATES *

By F. W. Mohlman

Director of Laboratories, The Sanitary District of Chicago, Chicago, Ill.

Editor of This Journal from 1928 to 1943, Dr. Mohlman writes here as an authoritative historical observer. His reminiscences are mainly slanted to Midwestern developments and personalities, but these men and their accomplishments have also been of significance in the broad progress of the sewage works field.—Ed.

A quarter of a century spans a good part of one's lifetime, and entitles one to a backward look and evaluation of professional developments, as seen in the light of experience and the test of time.

What progress has been made in these years? One could almost say offhand that no period of 25 years in American sewage disposal practice has ever approached the record of discovery, invention, and research that has characterized the years 1927–1952. Likewise, no period has ever seen so many processes, appurtenances, or ideas that failed to reach conventional application.

It is proposed to discuss the outstanding developments as seen by Middle Western eyes, their success or failures, some of the outstanding men in this region, and their impact on progress in the sewage disposal field. As one grows older, one is more inclined to advise young and active men to heed the history of the past more than to strike out along new lines, regardless of past failures in the same lines. On the other hand, this advice may stifle or curb the discovery of new processes or equipment, and uninhibited thought may foster the most important advances.

However, the thought and development of sewage disposal in the Central States have progressed conservatively, and if novel or unwarranted ideas have appeared, they have had to stand the tests of experimental study and plant operation before being accepted as permanent advances.

The development of progress in sewage disposal is reflected in the literature of the current period. Consequently, the outstanding papers by Midwest authors are reviewed in five-year periods, all of which papers from 1928 to 1943 the author personally read several times in the course of their road to publication.

Periods of Development

1928–1932

This first period of review, 1928–1932, was characterized by intense interest in heated digestion, variations of activated sludge treatment, chlorination, and chemical treatment of sewage.

The Antigo, Wis., plant was discussed at the 1928 meeting in Milwaukee, and Antigo became the Mecca of all true believers in heated digestion. The plant followed closely on the first application of a heated tank in New Jersey, but Antigo was the first full-size plant in which all sludge was digested by heat. The author still remembers the awe with which tales of the very concentrated sludge discharged and the high degree of digestion were received. Later in this period the digestion of activated sludge

* Presented at 25th Annual Meeting, Central States Sewage and Industrial Wastes Assn.; Madison, Wis.; June 25–27, 1952.

at Salem, Ohio, was another first; but not all subsequent investigations corroborated the low moisture content of the Salem digested sludge.

This period was largely one of dedication on the part of the author to the improvement and enlargement of the infant *Sewage Works Journal*, which grew lustily by the kindly cooperation of friends in the sewage works field. Among those not to be forgotten in this connection were W. W. Buffum, who steered the infant through its weaning period, and C. A. Emerson, the *pater familias* of the project.

Personally this was a busy period, with the Supreme Court Diversion Case hearings in Washington, D. C., opening of Chicago's North Side works, moving to a new laboratory, surveying the Flin Flon treatment plant in Northern Manitoba, and contact with experiments on activated sludge at Des Plaines and Calumet, Ill., and in the various laboratories of the Sanitary District of Chicago.

Milwaukee also was quite active in screenings digestion experiments, study of the German centrifuge used in Baltimore, control of industrial wastes, and thoughts on the theory of activated sludge treatment by R. Cramer.

Minneapolis-St. Paul approached the end of construction and J. A. Childs and G. J. Schroepfer were concerned with sewer rentals and Mississippi River conditions. H. O. Halvorson developed the super-chlorination procedure for packinghouse waters, later found untenable for various reasons.

H. F. Ferguson reported on sewage disposal progress in Illinois and E. E. Smith told pictorially of the benefits of chlorination at Elgin, Ill., in reducing filter growths and ponding.

C. K. Calvert, in Indiana, told of operating problems in the Indianapolis activated sludge plant, designed by C. H. Hurd.

Great interest became centered on chemical treatment, as practiced at Dearborn, Mich. Many observers pointed to the scientific rejuvenation of this almost forgotten phase of sewage treatment; but, alas, it soon was to regress again to a minor role.

Thermophilic digestion continued to intrigue investigators, but problems of insulation and odors balked steady progress.

W. B. Walraven pioneered in study and application of sewage sludge gas for the development of power.

1933–1937

The Minneapolis-St. Paul plant attracted many visitors because of its unique features of larger sedimentation tanks, the incineration of undigested sludge, and the somewhat dubious inclusion of magnetite filters for "polishing off" the settled effluent—the filters later to be abandoned. Chemical treatment, although installed for operation, never did become a reality. However, the plant set records for economical operating cost.

Many studies of treatment, measurement, and control were made. M. B. Owen told of two years of operation of the Dearborn, Mich., plant, quite the center of attention at the time. The Guggenheim Process waxed and waned in tests at Chicago in 1933 and 1934. The Earp-Thomas miracle was unfolded near Chicago. The Maltby Biologic Wheel revolved at Hammond. Garbage digestion studies flourished in 1935.

Packinghouse waste treatment progressed vigorously at Madison, Wis.; Sioux Falls, S. Dak.; and Cedar Rapids, Iowa. H. N. Jenks, M Levine, and H. O. Halvorson attracted world-wide attention by their epochal studies of high-rate biological filtration, and thus redeemed the moribund process of low-rate biological filtration from its condition of suspended animation.

Mechanical handling of sludge was studied at Chicago, and the "flash" type of dryer developed, leading to the later installation for all Chicago activated sludge.

W. A. Sperry demonstrated the advantages of the gas engine at Aurora,

Ill., and quoted impressive data as to its economy.

Earp-Thomas aroused interest with his tales of trained thermophilic bacteria from Australia, an idea still reiterated by devotees of the Kaiser-Frazer and "Golden Garbage" schools of thought.

The Halvorson high-rate filter was on exhibition in 1935 in Minneapolis, Minn., and visitors were startled by claims that trickling filter rates of from 5 to 10 m.g.a.d. resulted in clogged filters, but that these disadvantages were eliminated at rates of 15 or 20 m.g.a.d. However, it should be noted that this work has led to very substantial progress in the field of sewage treatment and we should be proud of Dr. Halvorson in the Central States for his pioneering work in this field. Levine and Jenks, of Iowa, were also pioneers in this development.

This was probably history's most active period in promulgation of new ideas in sewage treatment. The Nordell Number was studied by Kessler for activated sludge operation, and considered by him to be a revolutionary concept in this field.

Meanwhile, steady progress was registered in construction of sewage treatment works, and the plants at Chicago, Minneapolis, and Milwaukee, as well as at Waukegan, Rockford, and Galesburg, Ill., started operation. The plants at Peoria and Decatur, Ill., and at Madison and smaller communities in Wisconsin, were turning out valuable operating results and Urbana-Champaign, Ill., was well publicized by the highly developed public relations sense of Gus Radebaugh, who died near the close of this period.

1938–1942

In this era, considerable interest was shown in the advantages of series digestion in heated tanks, as exemplified at Aurora and Peoria, Ill.

The plants at Gary and Fort Wayne, Ind.; Kenosha, Neenah–Menasha, and Green Bay, Wis.; and the enlarged Nine Springs plant at Madison, Wis., started operation. At Chicago, the world's largest, the Southwest treatment works, lumbered into the first stages of operation.

The "Equilibrium Index," introduced by Mallory as a tool in activated sludge process control, attracted wide interest. His conference and demonstration at the Ann Arbor, Mich., plant in 1943 created quite a stir in sewage circles.

The ozone process was revived on the West Coast, but did not find much consideration in the Midwest.

The Dorr Company introduced the "Vacuator" and the Putnam Process was promoted by Polley at San Antonio, Tex., after all interest had died in the Central States. However, the process had a later resuscitation in Chicago for awhile.

Indianapolis lagoons were the object of considerable attention, largely curiosity because of their longevity.

However, the dominant interest in this period was the progress of World War II (1939–1945). Soon after the first year, military matters supplanted most civil interests, sewage treatment plants were operated under difficulties, and new construction was postponed. Industrial wastes became of increasing importance, and especially ordnance and military wastes occupied much time. In the Central States there were the Kankakee, Plum Brook, Badger, Weldon Springs, and Minnesota ordnance plants, among others, and disposal of TNT wastes became the most urgent problem of the time. Army camps mushroomed, and the design, construction, and operation of such plants became of first importance. The Hays Process came to attention, but its application was largely limited to army camps and it has not been significant in the Midwest scene.

1943–1947

The heights of war work were reached and passed during the period from 1943 to 1947, and normal sewage

works construction and operation returned with renewed vigor. Personnel problems, which almost wrecked plant operation, were less acute and normal repair materials could again be purchased.

Only the convention in the critical year of 1945 had to be by-passed by the Association because of travel restrictions, and papers during 1946 and 1947 were somewhat restricted, due to delay in return of the engineers and chemists to peacetime pursuits.

During this period there was such a shortage of fats and the price became so high that for a while grease recovery from sewage was profitable. Such recovery waned, however, as soon as the war was over. Grease extraction was promoted by a company in Indiana and Illinois but the process never reached practical operation.

The Lewis, or Marl Process was revived in Ohio briefly in 1946, but activities were soon transferred to Pennsylvania.

A suit, started between the States of Illinois and Indiana, over the pollution of the southern end of Lake Michigan, resulted in the expenditure of more than $15,000,000 by the Calumet, Ill., industries and the installation of the world's largest A.P.I. skimming tanks by the Standard Oil Company of Indiana. Also, sewage treatment and waste abatement procedures were instituted by the concerned industries, resulting in considerable improvement in the waste conditions when the suit was dismissed by the Supreme Court in 1948.

Industrial waste abatement received considerable impetus after the close of the war, resulting in the devotion of greater emphasis to industrial waste papers in the former *Sewage Works Journal*.

Activated sludge was "stream-lined" by reducing the aeration period to 2 or 3 hr. and the aeration tank solids to 500 to 600 p.p.m. This modification was claimed as a new discovery, mainly in the Eastern states, and never was practiced in the Midwest, except possibly involuntarily, when solids could not be retained in the system. This is discussed later.

Considerable interest developed during this period concerning possibility of transmission of poliomyelitis by sewage or sewage sludge. However, theories did not have much confirmation by results of plant operation, and at present there is little fear of sewage as a source of this disease.

During this period, on February 6, 1944, Paul Hansen died, a grievous loss in the Central States, because of his active interest in the Central States Association and his organization of its first meeting in 1927.

1948–1952

Thus we come to a period marked by the expansion of the U. S. Public Health Service to an unprecedented degree and the formulation of ambitious plans, following the passage of Public Law 845 in 1948, for control and abatement of sewage and industrial waste pollution throughout the United States. The Central States Association can be proud of its former members, including Ruehhoft, Warrick, Schwob, LeBosquet, Black, Reed, Martin, Mackenzie, and Kramer, who now direct much of the national work of the U.S.P.H.S.

Large new plants in the period 1948–1952 were almost negligible, but smaller plants have grown rapidly. Industrial wastes have supplanted the former interest in and expenditures for sewage treatment, and a healthy interest is seen in the Central States in studies of treatment of various industrial wastes.

One of the most fertile fields of investigation is the problem of detergents in sewage. Nearly all plants can provide data on frothing of aeration tanks and there seems to be no doubt of the ubiquity of this nuisance. In fact, the worst case of frothing seen by the author was present on the surface of the aeration tanks at the Mogden plant,

Middlesex, England, in July, 1951, although Superintendent Lockett was not greatly concerned about the phenomenon, as he found no deterioration of the effluent.

Toxic wastes occupy the attention of Midwest chemists, particularly of Dr. Hatfield, who has done so much nationally recognized work on methods of analysis and limits of various substances below toxicity levels. Also, the Midwest has been very conscious of the detrimental effect of small amounts of copper in sewage, actually undergoing a lawsuit or two before this problem was solved. Cyanides, chromium, and phenol have been studied and their removal planned, by precipitation or oxidation.

Radioactive wastes are not spread widely through the Central States, except for the center of research at the Argonne Laboratory, near Chicago. So far, no difficult problems have arisen from the proximity of the work to the enormous population of Chicago.

Thus, it appears that industrial wastes are now receiving most attention in the sewage works field, either alone or in combination with sewage, and many new ideas are promulgated, such as the use of flotation devices (Gibbs, Bulkley-Dunton), spray irrigation (typical of pre-war Germany), lagoons (with or without sodium nitrate), and vibrating screens. However, it is hoped that the principles of treatment of organic wastes, as developed in the sewage field, will not be forgotten. High-rate biological filtration is still a rather potent possibility and, fortunately, many manufacturers are including it in their roster of available processes.

Memoirs of 25 Years

In this review of the past quarter century, it hardly seems fitting to overlook the names of former associates who have added much to the progress of sewage disposal in the Central States. To recall these men is not simply *"de mortuis nil nisi bonum,"* but really an expression of appreciation for the impression they made on the pages of progress in our field.

T. C. Hatton was one of the earlier stalwarts who cannot be forgotten, because of his bold espousal of new ideas and his courage in making his ideas come true.

J. A. Childs was a pioneer in the Northwest, introducing new ideas in the field of stream pollution evaluation, and the designing of sewage works to meet the needs of the stream.

James Mackin, Sr., can still be remembered with affection as a pioneer and a sturdy worker in the practical field of sewage treatment.

Gus Radebaugh is vividly remembered for his unfailing personal magnetism and his consistent advocacy of the advancement of sewage treatment in the Central States. As its first Secretary, he did invaluable work to build up the CSIWA.

Paul Hansen was a man remembered for his charm of manner, as well as his ability as a sanitary engineer or his pioneering work in establishment of the Central States Association.

Harry F. Ferguson had much to do with the installation of sewage treatment works in the state of Illinois, and his name should not be forgotten. Cecil Calvert was equally revered in Indiana and his host of friends in the Association still miss him.

This brief reference to those who have left is due them, but should not detract from equal consideration for others, as well as their living confreres.

Thoughts on Activated Sludge

As the author has lived with the development of the activated sludge process since his first experiment, started at the University of Illinois on November 2, 1914, possibly he can be permitted to inject a few words concerning the control of operation of such plants as are now in operation.

This is done with pride in the steady progress and solid accomplishments of the activated sludge plants in the Mid-

west, but also with a look askance at the low estate to which the process has been brought, what with shortening of aeration periods, skimping of air application, reduction of the solids in the aeration tank, reverence for sludge age, and trick uses of various indices applied to the sludge in the aeration tanks.

The low solids developments are deplored, unless the index of the sludge is so high that it cannot be built up to a desirable concentration. Kraus has learned how to manipulate the sludge to give it a lower index. As everyone knows, such methods permit shortening the aeration period and stabilizing plant operation.

Also, everyone knows the difference between plain aeration of sewage and the activated sludge process, but there seems to be a tendency to reduce the solids below the range of the latter, say to less than 500 p.p.m. in the aeration tanks, and to accept inferior effluents and plant vagaries in lieu of true activated sludge stability.

Of course, Calvert showed years ago that by plain aeration one can obtain not only a measurable increase in removal of B.O.D. over sedimentation, but also a fairly dense sludge. He operated thus, however, by reason of necessity, not by choice.

The author is a strong proponent of control of the process in the field in which it was developed, say around 20 per cent (now more) sludge return, at least 1,500 p.p.m. solids in the mixed liquor, maintenance of 3.0 p.p.m. or more dissolved oxygen in the aeration tank effluent, and careful daily attention to the sludge index, no matter how determined. The sludge age is a secondary consideration, and after a year's study of this as a control factor at the Chicago Southwest treatment works, it was abandoned and a return was made to what seemed to be a more sensitive index—parts per million and sludge index. However, it is apparent that the sludge age varies directly as the concentration of mixed liquor solids, and if one has an age of one-half day or less, it is merely another way of stating that the process is not activated sludge, but a slight variation of plain aeration.

These conclusions are based on observation and preparation of nearly 500 weekly reports on the Chicago Southwest activated sludge plant over the past 10 years. Faith is put in the control tests just described and it is believed that a trouble-free activated sludge plant can be operated in the face of many industrial waste difficulties.

It is also believed that most Midwest plants follow the same procedure, and do not attempt to make of the activated sludge process something for which it was never intended. In this conservative way is followed the example of Britain's largest plant, at West Middlesex, in adhering to the original principles of the activated sludge process.

If abbreviated processes or impaired effluents suffice, there are other procedures (such as chemical treatment, high-rate filters, or plain aeration, with its accompanying hazards from detergent frothing) which can be used, without resorting to endless modifications that ruin the obvious high quality of the activated sludge effluent when operated in the intended manner.

Sewage Disposal in General

A final glance backward for 25 years only strengthens one's feeling that sewage disposal in the Central States has progressed conservatively yet steadily, and that probably in the field of sludge disposal the region has the most varied and complete processes now extant in sewage practice. There is a long vista of development ahead for industrial waste disposal practice, stimulating to new endeavor and research in this field. Let us keep as our slogan: "Prove all things; hold fast that which is good."

ROTARY TUBES AS EXPERIMENTAL TRICKLING FILTERS

By Earnest F. Gloyna, Robert F. Comstock, and C. E. Renn

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During the 1951–52 school year the authors have carried on a number of investigations on the susceptibility of various industrial and domestic wastes to trickling filter treatment. In these studies there has been employed a simple laboratory "equivalent" to the conventional stone trickling filter, the design of which should be of interest to industrial waste and sanitary engineering laboratories. The "equivalent" used has great advantages over common miniature and small-scale trickling filters in permitting more rational analysis of filter functions. The common range of data from general practice, experimental filters, and the units described shows that the apparatus may be used with confidence.

In brief, the trickling filter "equivalents" (Figure 1) consist of a series of rotating plastic tubes inclined slightly from the horizontal. Raw wastes are fed into the upper end of the rotating tubes and the effluent is drained from the lower end. Analyses of the influent and effluent yield differences that measure treatment. The units used are Lucite and Plexiglas tubes 24 in. long with inside diameters of 2¼ in. These are rotated at a speed of 16 r.p.m. The influent liquors are fed from positive-drive metering pumps at rates (based upon effective wetted surface) equivalent to low-rate or high-rate filter treatment. The liquor retention or flow-through time can be varied by changing the off-horizontal angle of the tubes.

In the actual unit used (Figure 2), 6 tubes are series driven from a gear reducer. Many design variations are possible. It is only necessary to provide smooth bearing surfaces for the plastic tubes and to assure positive driving through chain connections.

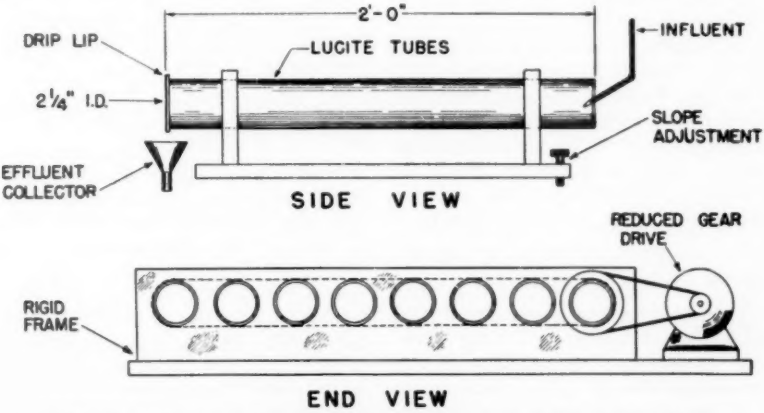

FIGURE 1.—Working drawing for rotary tube "equivalent" trickling filters.

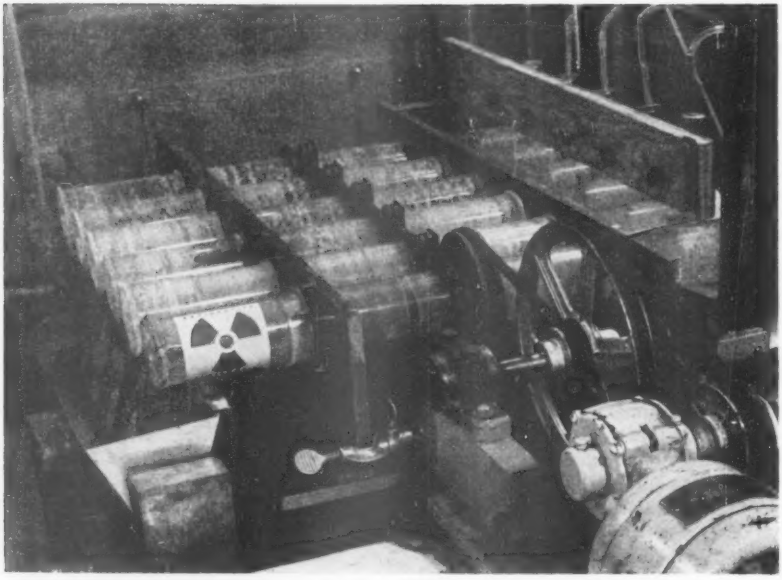

FIGURE 2.—Rotary tube filter unit as used in laboratory work.

Advantages of Tubes

It is found that the rotary tubes function like the trickling filters in the following respects:

1. The microbiological slime film growths on the interior walls of the tubes are identical to those on stones of conventional beds.
2. A fixed wettable area is irrigated by controlled flows of waste.
3. The loading rate is determined by the feed rate and the concentration.
4. Recirculation or series operation may be had by returning effluent to primary or secondary tubes.

The rotary tube equivalents have some peculiar advantages for experimental work, as follows:

1. They take less space than filters of equivalent capacity.
2. They are more accessible and more easily maintained.
3. The effective active surface is defined and directly measurable.
4. Active slime may be removed *in toto* for special studies.
5. They are activated more quickly and recover from "slug" damage more rapidly than do trickling filters.
6. They do not clog with fibers or grit.
7. The equipment is portable; an 8-tube unit with pumps and accessories may be carried in the luggage compartment of an automobile.
8. The design may be adapted for small volumes of waste, without distribution limitations.

It has been found that the functional performance of rotary filters is very close to that of equal wetted areas of conventional trickling filters. One of the rotating tubes operating at a dosage rate of 7 l. per day of settled domestic sewage has an irrigated wetted surface and flow-through equivalent of a 6-ft. deep bed of 2-in. stone loaded at the rate of 8 m.g.d. At this loading, using Butterfield's synthetic sewage in the range of 250 p.p.m. B.O.D., there

TABLE I.—Performance of Rotary Tubes and Experimental Filter with Synthetic Sewage

Unit No.	No. of Tests	B.O.D.		Ammonia N (p.p.m.)		Total N (p.p.m.)	
		Applied (p.p.m.)	Removed (%)	Infl.	Effl.	Infl.	Effl.
(*a*) Rotary Tubes							
#1	6	265	87	25.3	65.6	91.0	87.0
#2	7	260	82	34.6	50.3	85.8	81.1
#3	8	244	83	26.6	54.8	87.2	80.0
#4	7	251	83	26.4	47.0	89.8	83.0
#5	6	246	82	26.3	59.8	88.1	80.0
#6	8	245	83	28.0	59.0	88.3	81.4
(*b*) Trickling Filter							
	14	265	92	20.3	33.8	85.7	88.0

TABLE II.—Summary of Influent and Settled Effluent Analyses from Rotary Tube Operation with Domestic Sewage

Daily Tests	B.O.D.		Ammonia N (p.p.m.)		Nitrite N (p.p.m.)		Nitrate N (p.p.m.)	
	Applied (p.p.m.)	Removed (%)	Infl.	Effl.	Infl.	Effl	Infl.	Effl.
8	174	88.5	31.6	47.7	0.00	0.38	4.3	4.8
6	245	91.1	28.2	48.7	0.00	3.87	8.8	14.8
7	328	84.5	32.3	39.6	0.03	4.38	7.6	19.6
10	574	62.4	32.5	68.0	0.01	1.93	8.8	10.4

is a B.O.D. removal of approximately 85 per cent. Only trace concentrations of nitrite and nitrate are formed; the ammonia concentrations of synthetic waste effluent are doubled. Typical performances of the rotary tubes fed Butterfield's synthetic sewage are given in Table I (*a*). These may be compared with the performance of one of the laboratory trickling filters, an 8-ft. column filled with ½-in. river stone, for which 14 runs are averaged in Table I (*b*). Both types of filters were fed at rates based on equivalent wetted surfaces.

Tests on flow-through time made with I^{131} show that the rotary filters in these tests had a slightly more rapid flow-through time. The mode was reached in 20 min., the mean in 50 min. In the laboratory stone filter, the mode was reached in 25 min., the mean in about 60 min. These differences may account for the slightly higher B.O.D. removal obtained with the trickling filter.

The rotary tube equivalents respond to rising concentrations of influent wastes in much the same manner as the trickling filters. When fed at the equivalent rate of 8 m.g.d. per acre of 2-in. stone, 6 ft. deep, approximately 90 per cent of the B.O.D. is removed from settled domestic sewage in the common range of about 200 p.p.m. The percentage removed decreases with rising concentrations of influent B.O.D. At 574 p.p.m. approximately 60 per cent of the B.O.D. is removed. Table II summarizes experience with 31 tests with settled domestic sewage. The older settled domestic sewage nitrifies much more readily at this higher rate than does fresh synthetic sewage.

STATISTICAL ANALYSIS OF TRICKLING FILTER DATA

By John M. Fairall

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The Metropolitan Sewage District of Green Bay, Wis., in 1948 operated two experimental filters 8 ft. in diameter by 3 ft. deep. They were dosed at constant rates with settled Green Bay sewage, with provision for sampling the sewage after passing through the first 1 ft. of rock of filter No. 1. This was settled for 1 hr. and the supernatant was considered to be equivalent to sewage settled in a final clarifier. Effluent from the filters was settled in final clarifiers.

In evaluating these data, the percentage of 5-day B.O.D. remaining was calculated based on the strength of the filter influent, recirculation included, to the strength of the final clarifier effluent. The percentages remaining were then arranged in order of increasing values for various runs (Table I) and plotted on normal probability paper by methods indicated by Velz (1). Filter No. 2 operated from June 6 to July 9 and July 14 to August 9 at a dosing rate of 8.27 m.g.a.d. The results are plotted in Figure 1. Other runs on these filters were similarly plotted and the results are tabulated in Table II.

Since the data fall on a straight line,

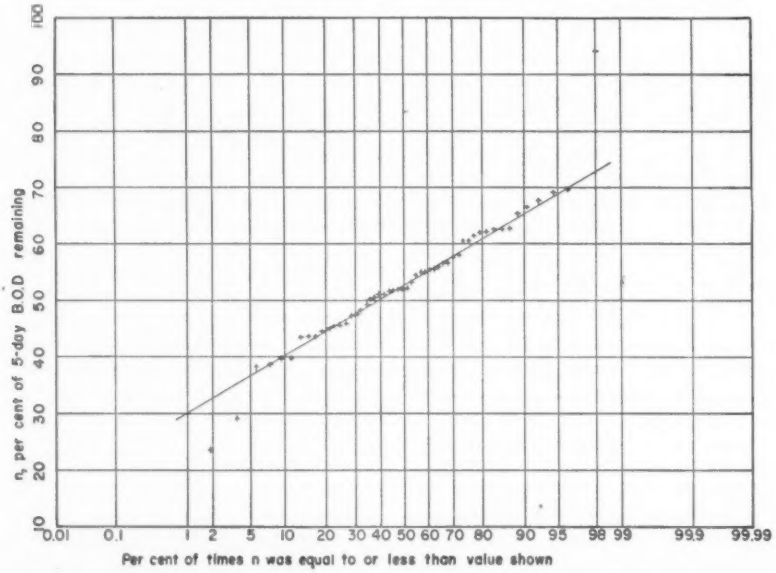

FIGURE 1.—Observed frequency of remaining B.O.D. percentages in experimental filter effluent.

TABLE I.—Statistical Data for Filter No. 2 in Order of Increasing B.O.D. Percentages Remaining in Effluent (Dosing Rate = 8.27 m.g.a.d.)

Serial No., M	B.O.D. Remaining, n (%)	Date	Sew. Temp. (°F).	B.O.D., Infl., c_1 (p.p.m.)	B.O.D., Effl. (p.p.m.)	Serial No., M	B.O.D. Remaining, n (%)	Date	Sew. Temp. (°F).	B.O.D., Infl., c_1 (p.p.m.)	B.O.D., Effl. (p.p.m.)
1	23.8	8/8	68	80	19	27	52.	6/6	62	75	39
2	29.2	8/9	69	178	52	28	53.4	6/24	65	203	108
3	38.2	8/7	70	167	64	29	54.5	6/27	65	90	49
4	38.8	7/25	68	116	45	30	55.	7/8	67	204	112
5	39.6	8/5	69	174	69	31	55.	6/8	63	182	100
6	39.7	8/4	69	136	54	32	55.5	7/2	66	164	91
7	43.5	6/28	66	133	58	33	55.5	7/31	70	137	76
8	43.6	8/2	69	190	83	34	56.	6/15	65	203	114
9	43.6	8/1	69	71	31	35	56.5	6/25	67	219	124
10	44.6	7/29	70	170	76	36	56.6	6/14	64	159	90
11	45.	7/21	69	149	67	37	57.6	6/23	64	210	121
12	45.4	7/26	70	234	106	38	58.	6/19	63	148	86
13	45.6	7/6	68	175	80	39	60.5	6/30	65	249	151
14	45.9	6/11	64	170	78	40	60.6	6/21	62	150	91
15	47.1	8/6	69	200	94	41	61.5	6/10	65	190	117
16	47.6	7/3	67	149	71	42	62.	6/9	65	211	131
17	48.4	7/5	67	189	43	43	62.	7/4	66	76	47
18	49.1	6/7	63	167	82	44	62.5	6/26	66	155	97
19	50.5	7/27	69	192	97	45	62.6	6/12	64	145	91
20	50.6	7/30	70	132	67	46	62.7	7/1	66	214	134
21	51.	7/23	68	155	79	47	65.2	6/18	65	164	107
22	51.	7/9	68	210	107	48	66.5	7/7	68	304	202
23	51.6	7/24	68	174	90	49	67.6	7/22	69	170	115
24	51.8	8/3	69	201	104	50	69.	6/16	65	212	146
25	51.9	6/29	—	185	96	51	69.4	6/17	65	222	154
26	51.9	7/28	70	212	110	52	94.0	6/20	65	81	76

$N + 1 = 53$ Std. Dev. = 9.6
Mean = 53.0 S.E. = 1.32

the variation of the percentage remaining is normal—the variation or deviation from the mean is that to be expected from chance alone.

It is to be noted in Table I that even though the data are arranged in order of increasing percentages of B.O.D. remaining, there is little evidence of the influent strength, c_1, similarly increasing. Since this filter was dosed at a constant rate, c_1 is proportional to the organic loading in pounds of B.O.D. per 1,000 cu. ft. In this filter there did not appear to be any correlation between organic loading and percentage of 5-day B.O.D. remaining.

There is 68 per cent confidence of

TABLE II.—Comparison of Statistical Values for Green Bay, Wis., Experimental Filter Data

Dates (1948)	Filter No.	Depth (ft.)	Rock Size (in.)	Flow Rate (m.g.a.d.)	Recirculation Ratio, R	Sew. Temp. (°F.)	No. of Samples, N	Av. B.O.D. Rem., n (%)	Std. Dev., σ	Std. Error
6/6 –8/9	2	3	2-3	8.27	0	62–70	52	53.0	9.6	1.32
6/23–7/9	1	1	4	16.01	1	64–67	16	73.	12.5	3.1
	1	3	4	16.01	1	64–68	17	75.	8.	1.94
7/26–8/9	1	1	2-3	16.01	1	68–70	15	63.	15.	3.88
	1	3	2-3	16.01	1	68–70	15	70.2	11.3	2.92
8/10–8/31	2	3	2-3	5.0	0	68–71	22	24.	11.	2.34
9/3 –9/23	2	3	2-3	7.75	0	68–71	21	40.5	9.5	2.08

enclosing the quality within the range (mean) ± (std. dev.) = 43.4 to 62.6 per cent; 95 per cent within (mean) ± 2 (std. dev.) = 33.8 to 72.2 per cent; and 99.73 per cent within (mean) ± 3 (std. dev.) = 24.2 to 81.8 per cent. If it was desired to use this same filter under the same conditions and be sure of its performance 98 per cent of the time, it would have to be designed on the basis of 72.2 per cent of the influent 5-day B.O.D. remaining, rather than on the mean of 53.0 per cent.

Experimental runs on filter No. 1 for the 3-ft. depth operating at 16.01 m.g.a.d. for 4-in. rock and 2- to 3-in. rock may be compared. For the 4-in. rock with a mean of 75 per cent remaining and a standard error of 1.94 per cent, if repeated series of 17 samples were taken from this filter at this dosing rate, the mean values might shift up or down. Ninety-five per cent of the means would fall within the range 75. ± 2SE = 75. ± 3.9. For the same conditions with 2- to 3-in. rock, 95 per cent of the means would fall within the range 70.2± 5.8. The range for the two sizes of rock would be 71.1 to 78.9 per cent and 64.4 to 76 per cent. Since these ranges overlap, chance cannot be ruled out and the difference between the two series is not accepted as statistically significant.

Returning to the headings of Table II, if 95 per cent confidence is required of the mean per cent remaining, SE = 2, then

$$N = \frac{(\text{std. dev.})^2}{(\text{SE})^2} = \frac{(9.6)^2}{(2)^2} = 23.5$$

so that 24 daily composite samples would be required.

Only carefully controlled experiments such as the ones at Green Bay will yield this type of information. Wide variations can be expected in the per cent of 5-day B.O.D. remaining, even with careful operation. A value determined on the basis of a set of 24-hr. composites, or even a run of a few days, cannot be relied on to give a mean value. Chance may yield a high value or a low value. A design based on mean values may quite often (by chance) yield an under-treated effluent. In fact, it is to be expected 50 per cent of the time. Comparison of experiments on a basis of mean values only may lead to conclusions when differences are not statistically significant.

Reference

1. Velz, C. J., "Graphical Approach to Statistics." *Water and Sew. Works*, **99**, 4, R–106 (1952).

AERATION EFFICIENCY AND DESIGN

II. Design from Pilot Plant Data *

By W. Wesley Eckenfelder, Jr.

Consulting Sanitary Chemist, Ridgewood, N. J.

The design of aeration systems is basically a problem of balancing the oxygen supplied to a system through a transfer mechanism from the gas phase to the liquid phase against the oxygen removed from the system by the active removal reaction. In activated sludge-sewage mixtures a three-phase system of gas, liquid, and suspended solids is present. It is necessary, therefore, to measure the oxygen requirements of the system under study and to measure the ability of the aeration system to satisfy these requirements. The oxygen is transferred by diffusion from air bubbles rising through the liquid. The quantity of oxygen transferred may be expressed as a transfer rate coefficient, k_d per unit of concentration gradient.† The total quantity per unit of time is $k_d(C^* - C_L)$, in which k_d is an overall coefficient for transfer from the gas phase, the liquid phase, and the area of transfer, and $(C^* - C_L)$ is the saturation deficit.

Oxygen will be removed from a system by chemical reaction, such as when sulfite is present, and by biological reaction, such as in the activated sludge process. Oxygen removal through biological mechanisms is a function of the concentration of sludge, the B.O.D. to be oxidized, the temperature, etc. The oxygen uptake rate will be determined by the types and numbers of organisms present and the physical and chemical properties of the environment. The oxygen uptake rate is proportional to the amount of active sludge and to the temperature. The oxygen uptake rate will be concentration dependent below a critical value. Above this critical value, the rate will be constant (5).

Kessler and Nichols (1) made an extensive investigation which led to the general conclusions that (a) the maximum oxidation rates are the same regardless of sewage strength with similar sludges with respect to quality and quantity, and (b) the quantity of active sludge employed was inversely proportional to the detention time for a given sewage strength. Ruchhoft *et al.* (8) and Hoover and Porges (9) found that of the total applied B.O.D. only a percentage is actually oxidized, the balance being used for assimilation and new sludge production. This percentage will vary with the type and character of a waste. In sewage treatment studies, 2.5 to 30 per cent was oxidized in 30 min., increasing to 30 to 60 per cent after 5 hr., these variations depending on the quality and quantity of sludge.

Bloodgood (3) found that the active oxidation rate varied from 14 to 20 mg. per hour per gram, and the endogenous rate 5 to 10 mg. per hour per gram for good sludge. Endogenous rates in excess of this value indicate a poorly oxidized sludge.

It has been established by several investigators that the oxygen demand rate is not constant through the detention period of the aerator, but varies

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* Presented at 6th Annual Meeting, Virginia Industrial Wastes and Sewage Works Assn.; Roanoke, Va.; May 12–13, 1952.

† The letter symbols adopted for this paper are defined in Part I, which appeared in This Journal, **24**, 10, 1221 (Oct., 1952).

with respect to time. The oxygen demand rate curve starts high, drops rapidly for 30 min., then falls to a final demand of one-third to one-sixth of the initial value. In industrial wastes the high initial demand may last for several hours. The oxygen demand rate will be approximately 1.65 times the average rate at the beginning of the aeration period and 0.4 times the average rate at the end of the aeration period. The practice of tapered aeration permits the oxygen balance to be maintained throughout the aeration tanks and the maximum economy effected. In a balanced aeration system the ratio of air required at the influent end to that required at the effluent end is approximately 4 to 1 (2).

An interrelation exists between the applied loading, the oxygen utilization rate, the dissolved oxygen present, and the air flow rate, which may be calculated for a given system. Figure 1 represents data from a pilot plant treating domestic sewage in which the air flow rate was modulated in response to the applied loading. In this system the dissolved oxygen in the system was maintained relatively constant. In many cases the air may be modulated during the day from loading data to effect the optimum economy. For this purpose a rapid estimation of loading conditions from a photometric measurement will suffice to serve as an index of air requirements. In many cases considerable

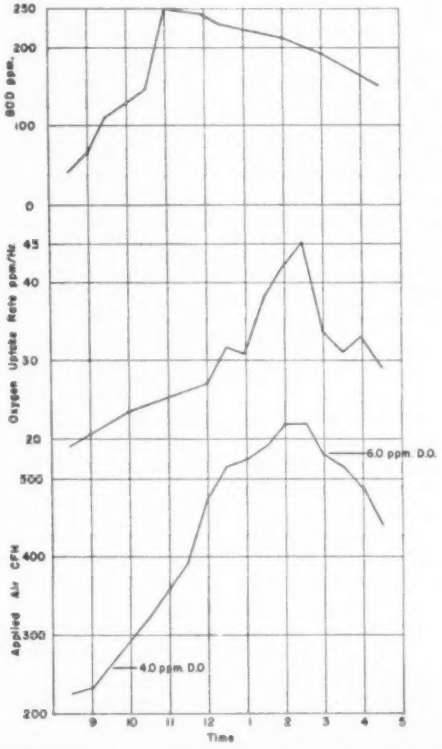

FIGURE 1.—Relation between B.O.D. loading, oxygen uptake rate, and applied air in continuous process operation treating domestic sewage.

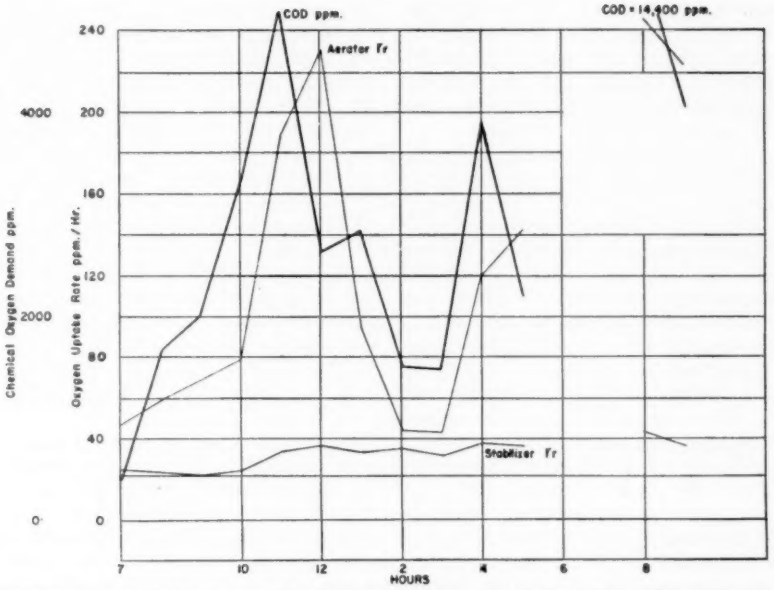

FIGURE 2.—Variation in oxygen demand rate and two-stage biological sludge treatment of apple waste.

power savings may be realized from this operation.

This same interrelation exists in biological sludge treatment of industrial wastes. Figure 2 represents data collected from a pilot plant treating apple wastes, employing the Biosorption process, in which the chemical oxygen con-

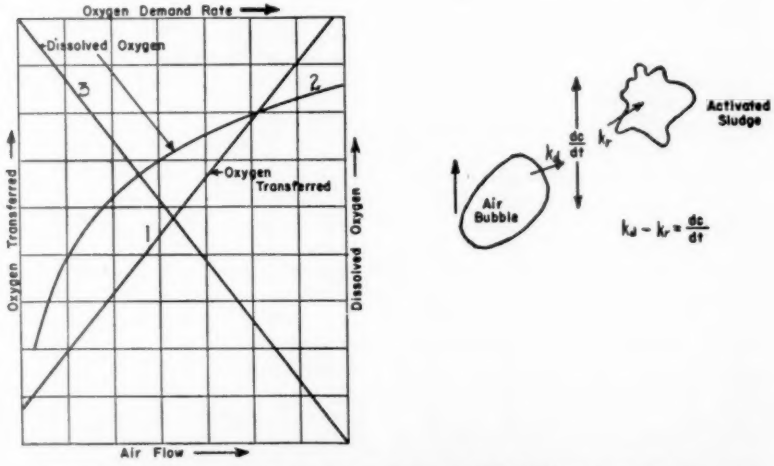

FIGURE 3.—The mechanism of oxygen transfer in the activated sludge process.

sumed was used as a loading criterion. It will be noted that the oxygen demand rate in the aerator closely followed the loading curve, whereas the stabilizer was somewhat evened out due to the detention time difference.

The increase or decrease in oxygen concentration in a given system may be expressed by Eq. 1c (6), in which K_d $(C^* - C_L)$ is equal to the pounds per hour of oxygen transferred to the system, K_r W is the pounds per hour of oxygen removed from the system, and dc/dt is the increase or decrease in oxygen concentration per unit of time. When insufficient oxygen is present, the metabolic rate of the sludge will be adversely affected and the system will be oxygen dependent.

Figure 3 is a schematic representation of the mechanism of oxygen transfer in a biological mixture, assuming steady-state conditions. In the case of a system where the oxygen utilization rate is substantially constant, an increase in air flow rate will result in a rapid increase in k_d (Curve 1) and an increase in the dissolved oxygen in the tank (dc/dt is positive) asymptotically approaching saturation (Curve 2). If the air flow rate is maintained constant and the oxygen utilization rate changes, the dissolved oxygen will increase or decrease (dc/dt positive or negative) in direct proportion to the change in the oxygen demand rate (Curve 3).

In continuously operating systems dc/dt approaches 0 for short time intervals, since the dissolved oxygen concentration does not change rapidly with respect to time and

$$k_d\ (C^* - C_L) = k_r W \qquad (11)$$

The design of an aeration system is then a function of supplying oxygen in response to its rate of utilization. These conditions assume that the overall rate of oxygen transfer is equal to the rate of removal by the active sludge.

The efficiency of an aeration system

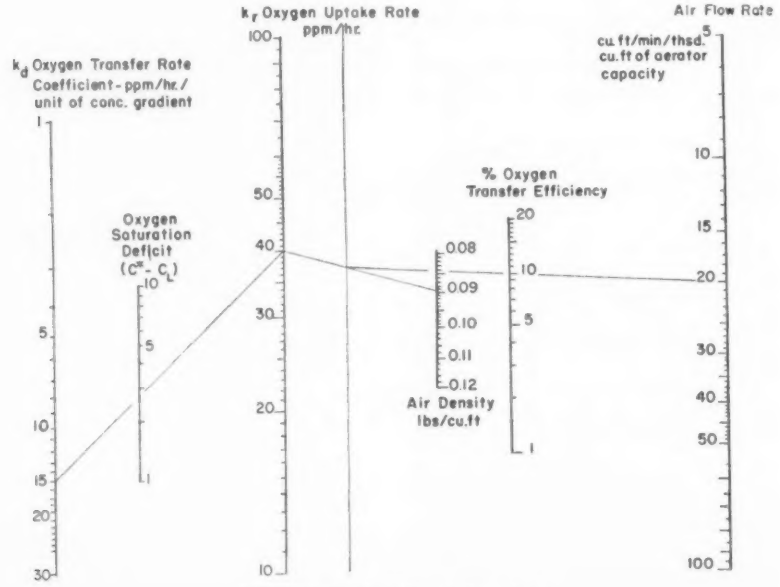

FIGURE 4.—Aeration design chart.

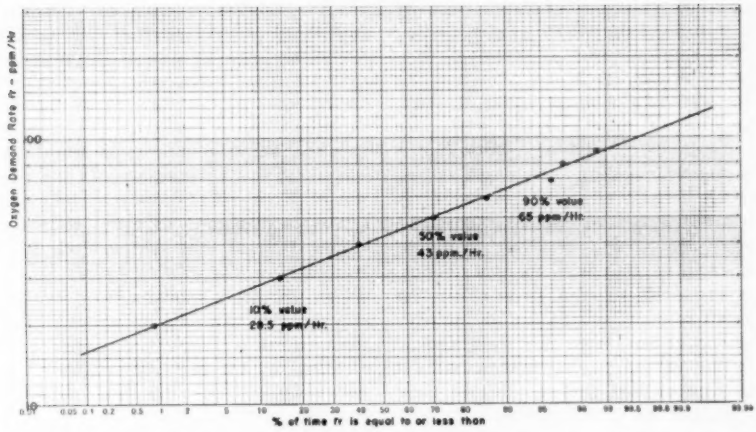
Oxygen Demand Rate r_r = ppm/Hr
100
10
10% value
29.5 ppm/Hr.
50% value
43 ppm/Hr.
90% value
65 ppm/Hr.
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.8 99.9 99.99
% of time r_r is equal to or less than

FIGURE 5.—Pilot plant investigation on the variation in demand rate of activated sludge treatment of cannery waste.

may be expressed by Eq. 6, in which $K_d\ (C^* - C_L)$ is the oxygen transferred and G_s is the oxygen supplied. For steady-state operation Eq. 6 may also be written

$$E = \frac{K_r W}{G_S} \times 100 \qquad (12)$$

To aid in the calculation of aeration data, a nomograph (Figure 4) is provided. From a knowledge of the oxygen uptake rate and the transfer efficiency, the required air flow and dissolved oxygen concentration in the aeration tanks may be readily computed.

Aeration design requires a knowledge of the aeration efficiency characteristics of a system and of the oxygen demand requirements. The efficiency characteristics may be measured (6). The oxygen demand requirements may be either measured through laboratory or pilot plant studies or estimated from a knowledge of the B.O.D.

Pilot plant studies, particularly in the case of industrial wastes, offer a direct and accurate measure of the air and power requirements. The procedure employed by the author is to gather oxygen demand rate data from grab samples at frequent intervals under representative loadings, solids concentration, temperature, and detention periods.

These data may be plotted statistically and the 90, 50, and 10 per cent chance values employed to represent the maximum, average, and minimum conditions.

Design Example

An example of aerator design from a pilot plant investigation of cannery wastes is as follows:

Figure 5 gives operating data on oxygen utilization rates in the aerator under varying applied load over an operating period of several weeks. From Figure 5 the oxygen utilization rate ($k_r\ W$) values are: 90 per cent, 65 p.p.m. per hr.; 50 per cent, 43 p.p.m. per hr.; and 10 per cent, 29 p.p.m. per hr. The aeration equipment to be employed has a measured oxygen transfer efficiency, to maintain 2.0 p.p.m. D.O. in the aerator, of 5.0 per cent. From Figure 4, the air requirement under maximum loading is 65 c.f.m. per 1,000 cu. ft. of aerator capacity, 43 c.f.m. per 1,000 cu. ft. of aerator capacity for average conditions, and 29 c.f.m.

per 1,000 cu. ft. of aerator capacity for minimum operation.

The concentration of dissolved oxygen to be carried in aeration tanks is a function of the temperature, the oxygen demand rate, and the economics involved. The dissolved oxygen in the clarifier effluent in most cases means very little and to a limiting extent is beyond operational control. Once the sludge leaves the aerators, it is no longer in contact with oxygen; hence, the dissolved oxygen present in the effluent is solely a function of the oxygen concentration in the sludge as it left the aerators, the oxygen utilization rate of that sludge, and the time of contact in the clarifiers. If the oxygen uptake rate were high, even saturation of the sludge with oxygen as it left the aerator would not insure dissolved oxygen in the process effluent.

The concentration of dissolved oxygen necesary to maintain optimum biological activity is 0.5 to 1.0 p.p.m. Concentrations in excess of this do not influence the oxidation rate, so that basic process economics discourage the maintenance of high residual dissolved oxygen.

From these data and oxygen transfer efficiency data, an aeration system and blowers can be designed. The operation of the aeration systems should be such that the air supplied is not in excess of that required for biological process efficiency for maximum economy.

The blowers should be designed with a view toward optimum efficiency of operation. A basis for blower design is: one blower for the minimum demand, a second for the difference between the minimum demand and the maximum demand, and a third designed to handle the maximum demand as a stand-by.

In the design it is desirable to strike a balance between solids to be carried and detention time with respect to the over-all horsepower requirements.

The operational control of activated sludge aeration systems may be simplified by a knowledge of the oxygen transfer characteristics of the aerating system. Once the oxygen transfer rate coefficients for a given system are established, the oxygen utilization rates may be rapidly computed from dissolved oxygen measurements by the use of Figure 4. Bloodgood (3) and others have found that the activated sludge process may be controlled by maintaining the sludge in good condition through a knowledge of its oxygen demand rate characteristics. For example, if a given system has a k_d of 10 at an air flow rate of 50 c.f.m. per 1,000 cu. ft. of aerator capacity and the measured dissolved oxygen is 2.5 p.p.m., the oxygen utilization rate of the activated sludge is 65 p.p.m. per hr. at a temperature of 20° C. The saturation value must either be determined or estimated for this condition. The oxygen demand rate may be obtained from the nomograph by drawing a line through the dissolved oxygen concentration gradient and the k_d value to the oxygen utilization scale.

This procedure enables an operator to keep a check on his sludge characteristics by dissolved oxygen measurements alone.

Modulation of the air supply through multiple blower control in many cases may be ascertained by the daily loading cycle if this is a constant. This would mean that during night flows blower No. 1 would operate to maintain the desired oxygen concentration. During the peak flow hours blowers No. 1 and No. 2 would be in operation, and in the evening hours only blower No. 2. This pattern may be established by the preparation of data as in Figure 1.

Summary and Conclusions

The basic process principle in the design and operation of aeration systems is to supply oxygen to the aerating mass in direct response to its rate of utilization. To accomplish this, it

is necessary to have a knowledge of the oxygen transfer characteristics of the aerating system and of the oxygen demand characteristics of the liquid mass. A nomograph is provided for the design of blower requirements from oxygen demand rate and oxygen transfer data.

An accurate estimate of process requirements may be made from pilot plant studies of oxygen absorption rate characteristics, under representative process conditions. This procedure permits the accurate design of aeration requirements for process demand. A method is outlined for the measurements of process operation with respect to the oxygen demand characteristics of an activated sludge from dissolved oxygen measurements alone.

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Industrial Wastes

POLLUTION ABATEMENT THROUGH WATER CONSERVATION—A SYMPOSIUM *

I. Water Conservation in Steel Mills

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The vital importance of water to the steel industry is not difficult to visualize. Not so widely realized, however, is the tremendous quantity of water consumed by a typical steel plant. Not only the quantity but also the quality of water is of prime importance, for different processes demand various quantities and qualities.

Water supply *versus* water usage has a definite bearing on whether or not water is conserved after its initial use. If the water supply requires extensive treatment for various applications or, as in certain instances, treated water is obtained from public supplies, the problem of conserving water becomes a major item in economical operations. Thus, recirculating the water after its initial use may often prove economical.

In an integrated steel plant, water is required for the following uses: service water for cooling, quenching, washing, etc.; special process water for boiler make-up; sanitary water for showers and flushing toilets; fire protection; and high-pressure service water for certain operations.

Inasmuch as the greatest volume of industrial water is utilized for general services, location of plants with respect to water supply definitely influences the necessity for conserving water. Even in plants where an abundant water supply is available, studies are conducted for the proper and most efficient methods of utilization, not only to conserve water, but also to minimize treatment costs.

What are some of these methods for conserving water to minimize treatment costs and pollution load? Several methods are practiced within the steel industry, depending on water supply availability and location of the plant with respect to downstream consumers. The following are typical methods for steel plants with abundant water, limited water, and very limited water supply.

Plant with Abundant Water

In a modern major steel plant much study is given to securing economical operation of the various facilities requiring general service water in relation to water supply and disposal, not only in accordance with the demands originating within the plant, but also in accordance with the requirements of downstream consumers.

The greatest volume of water is consumed for general services and clarified river water is readily adaptable for this function. Water withdrawn from the river passes through bar racks and conventional traveling screens equipped with automatic cleaning devices and is pumped to a settling basin designed to give 60 min. retention. This settling basin supplies in-

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dustrial water for the respective points of distribution and utilization. Approximately one-half the total abstraction from the river is consumed by the condenser water system, which supplies all water to the powerhouse, the turbo generators, and the turbo blowers, as well as miscellaneous cooling applications in that area. The remaining half of the total water abstracted from the river flows by gravity from the settling basin to a pumping station where the service water pumps discharge it into a distribution system supplying the major plant areas; that is, blast furnaces, open hearths, fire plugs, etc. All clean water from these systems is returned to the river or recirculated. The remainder is treated prior to its return to the river or to service water wells for repumping and recirculation.

The greater portion of cooling water from blast furnaces, after serving its purpose, is repumped and recirculated into the gas cleaning equipment for removing the flue dust from blast furnace gas. Naturally, some particles of the dust are absorbed by the cleaning water, which is then sent to a thickener for primary treatment. A retention time of approximately 80 min. allows the flue dust to settle to the bottom, where it is conveyed by a rotating scraper to the center of the tank, drawn off, and pumped to a sludge lagoon.

The effluent from the primary treatment facilities is discharged into a duct and carried to a secondary flue dust clarification plant. Here it enters a flash mixer (1-min. retention), where it is mixed with lime slurry. It then flows to a flocculator, where it is stirred gently by vertical propeller-type mixers to build up a floc heavy enough to settle, the detention time being approximately 25 min. The water containing the floc then passes to a clarifier with an estimated detention time of 2 hr. Effluent from the clarifier is discharged to the river, in a condition that will not impair the downstream quality. The outlet flume determines, by flow measurement, the amount of lime to be added to the flash mixer. It also has facilities to indicate, record, and total the water passing through the flume. The sludge deposited on the bottom of the clarifier is pumped back to the primary thickener.

All miscellaneous water, consisting of back-wash water, boiler blow-down water from the powerhouse and open hearth waste heat boilers, and wash-down water from other facilities, as well as the water from the scale removal pits in the rolling mills, is directed to the terminal wastes treatment plant. The main source of influent to the terminal treating plant is the scale removal pit overflow, which contains both mill scale and oil. All scale-bearing water is passed through scale pits with about 15 min. retention. Effluent from the oil interception plant, from which readily settleable solids have been removed, is also directed to the terminal treating plant.

At the terminal treating plant, the waste waters are lifted to an aeration basin by the terminal plant pumping station. This basin provides about 5 min. detention. From the aerators the liquid waste passes to a mechanically cleaned presedimentation basin providing a 16-min. retention period. Sludge from this basin is pumped to a lagoon.

The presedimentation basin effluent then passes to a large sedimentation basin, providing a 4-hr. retention period. Scum is retained by skimming weirs at the outlet end of the basin for withdrawal and pumping to scum thickeners.

From the large, or secondary sedimentation basin the effluent is conducted to a storage reservoir, where an additional 4-hr. retention is provided. The clarified water may either be discharged to the river or enter the service water system of the plant. The latter is provided because of the high degree of treatment these waters received, and their character at this point will be essentially equal to the quality

of the river water taken into the service water system.

Periodically, each compartment of the secondary sedimentation basin is emptied and the sludge removed. The oil waste, together with what little other waste there is coming from the other respective parts of the steel plant, is all segregated and treated separately for recovery of oil. The oil treatment plant effluent goes to the terminal treatment plant as heretofore described. This oil interception or treatment plant consists of a flocculator, a clarifier, and a sedimentation basin. The clarifier effluent goes through an oil separator for further clarification prior to entering the terminal pumping station for regular processing treatment.

Treatment facilities provided for sanitary sewage consist of a pumping station, a primary tank, trickling filters, a secondary tank, and chlorinating equipment. Chlorination of the effluent is effected in a contact tank providing 20 min. detention. The final effluent is measured and discharged into the stream.

In conjunction with the general waste and sanitary waste treatment plants, separate sewer systems are provided.

Plant with Limited Water

Then there is the case wherein water supply is limited to a certain extent and additional treated water is obtained from public suppliers. In this instance water is abstracted from the river and limed prior to entering the plant. The greatest interest at this point is in condenser water and general service waters, as they are the greatest consumers. After the water serves its purpose as condenser water, it is repumped and used for blast furnace and open hearth service water.

Additional water is also pumped directly to the blast furnace standpipe and the open hearth standpipe. The water from the branch serving the blowing rooms is repumped as service water to other related facilities and also to the mills, pig machines, car dumpers, screens, etc., and then directed to the open hearth standpipe. The question might be raised as to why there are so many cooling water inlets into the open hearth standpipe. Such extensive distances are encountered in the plant under discussion that to obtain sufficient pressure and sufficient capacity of water in the open hearth would require extensive pumping. Therefore, the basic principle of recirculating and re-using this water from the respective points of use is all concentrated to the open hearth standpipe, wherein sufficient water is available for open hearth cooling.

Because there have been some additional facilities installed requiring even more water and the present system is inadequate to serve them properly with the necessary cooling water, water is obtained from a public supplier and sent to a closed system which is independent of the other systems. A pump of sufficient capacity on this system will completely circulate water through a condenser and a cooling tower. Very little water is lost in evaporation, the total make-up required amounting to about 2 to 3 per cent.

Another interesting sidelight in regard to water obtained at this plant from a public supplier is that it is sent through the blowing engines to cool them, which incidentally heats the water as required prior to its being treated for additional uses such as boiler feed water.

Plant with Very Limited Supply

Finally, there is the plant where water supply is absolutely limited as there is no stream close to the plant. In this case water use must be applied judiciously. The supply of industrial water for the various mills, coke ovens, and coal washing plants, is obtained principally from a reservoir containing

impounded water and located about 8,000 ft. from the plant. Water is delivered to a pumping station through a tunnel, and self-cleaning screens are installed at the suction well adjacent to the pumphouse.

When one considers that some 44 m.g.d. are used, careful consideration must be given to conservation of water. The water is used chiefly for cooling purposes, also for steam generation after chemical treatment (1). Only a small part of the water is allowed to waste after its initial use; the greater part being used as make-up in the numerous water reclaiming systems throughout the various parts of the plant, where it is cleaned by means of screens and settling basins, cooled by spray ponds or cooling towers, and then re-used. The water recirculated in this manner amounts to approximately 200 m.g.d.

In the turbo blowing rooms, for instance, two turbo blowers exhaust into surface condensers; two other blowers are equipped with barometric condensers (2). Water for use in these condensers is circulated over 10 bays of cooling towers of both forced-draft and atmospheric design. The basins are so arranged that circulating water for the surface condensers can be segregated from that used in the barometric condensers.

Likewise, cooling water for furnaces and auxiliary blast furnace equipment is recirculated by a group of centrifugal pumps and reciprocating pumps located in a central pumphouse. Make-up water is supplied by the plant distribution system from the original impounding reservoir.

The off-water from the blast furnaces and the open hearth systems is returned to a spray pond system for cooling. The off-water from several mills is also diverted to an impounding system where it is pumped to the spray pond system. The latter system also serves as the source of supply to the circulating pumps for other uses throughout the plants.

It is interesting to note that even with the large volume required, a clever system of spray ponds, cooling towers, and recirculation limits the amount of make-up water used to that which is lost through evaporation.

Conclusion

In conclusion, every operator knows the importance of keeping general plant and mill water clean. It is imperative that high-pressure descaling water be free from dirt and foreign matter to keep the nozzles open. It is also important that the lines to spray nozzles and other equipment be kept clean to avoid build-up and plugging of the lines. In some cases, shock chlorination is applied to incoming water to prevent build-up or tuberculation in the cooling and recirculation facilities. Also, if possible, equipment is designed so that there is a very small change of velocity throughout the various pieces of equipment in order to maintain a uniform water flow and thus prevent deposits. When the water returns to its original source or treatment plant, it is in a condition where minimum treatment, if any, is required.

Stream pollution abatement is becoming a major item and the starting point naturally would be the waste reduction or elimination, and adoption of methods which are judged best. If the incoming water is dirty so that it can't be returned clean and if excessive expenditures are required to clean the water, the use of recirculation should be adopted.

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II. How Four Oil Refineries Use Water

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The title "How Four Oil Refineries Use Water" may seem somewhat off the subject in a discussion on the reduction of pollution load by water conservation. However, a description of the use of water in a number of refineries will serve to illustrate the water problems faced by the industry and the place of water conservation in petroleum refining. The members of this group by the nature of their work and interests are obviously aware of the importance of water to industry in general. An illustration of the importance of water in refining in particular is of interest. It is surprising to note that the largest single item in refinery operating expense is fuel cost. A typical 50,000-bbl. per day refinery, not large as refineries go, burns more than 1,000,000,000 B.t.u. per hour. Approximately 50 per cent of this heat must be removed by water in one way or another. Relatively small quantities of water are required for purposes other than heat removal. Such a refinery would require in the neighborhood of 40,000 g.p.m. of water at a 30° F. temperature rise. This quantity of water would supply the domestic requirements of the city of Toledo, Ohio.

The manner in which such quantities of water are supplied and used varies according to local circumstances. In the past, the type of water utilization depended almost entirely on the economics of the particular situation. In those cases where there was an abundant supply of cheap, good quality water, the water was used on a once-through basis and discharged as a waste. Where water costs were high, or water scarce (sufficient water may be unavailable at any price), cooling towers were built so that water could be recirculated, thus minimizing water consumption and water cost. At present these factors are still important, for they are economic factors. Nevertheless, the type of water usage is being influenced more and more by considerations of stream pollution. There is an increased awareness on the part of both industry and the public of the importance of water conservation in general. Reduction of stream pollution is a form of water conservation. Since waste treatment costs to prevent stream pollution can be very expensive and are a function of the volume to be treated, it is evident that the degree of treatment which a waste water effluent must receive can dictate the water system chosen.

TABLE I.—Comparative Data for Water Use at Four Ohio Oil Refineries

Refinery	Crude Run (b.p.d.)[1]	Fresh Water Used (g.p.m.)	Water Circulation (g.p.m.)	Fresh Water per Barrel Crude (gal.)
Toledo, Ohio	21,000	27,200	0	1,870
Cleveland, Ohio	44,000	9,500	35,200	311
Lima, Ohio	39,000	3,900	40,400	144
Latonia, Ky.	15,000	765	15,800	73

[1] Barrels per day.

Sohio operates four gasoline refineries, no two of which use water in the same manner. The systems vary from a strictly once-through system to a completely recirculating system. Local costs, availability of water, and the pollution factor have governed the selection of the individual systems.

Table I shows a comparison, for each refinery, of the crude run, water circulation rate, fresh water charged, and quantity of fresh water used per barrel of crude processed. The last item,

which varies from 1,870 gal. of fresh water per barrel of crude to only 73 gal. per barrel, is an index of the degree of conservation employed.

Toledo Refinery

At the Toledo refinery the water system is simple. The refinery is located a short distance from Maumee Bay, which furnishes a cheap, unlimited supply of relatively low-temperature water. Therefore, economics dictated once-through use of the water. The disadvantage of this system is that a large and expensive oil-water separator is required to handle the large discharge returned to the bay. Should additional treatment of this waste stream be required, it is obvious that the 27,000-g.p.m. waste volume will have to be reduced—at great expense.

Cleveland Refinery

At Cleveland, the situation is considerably different. The Cuyahoga River is the cheapest source of water, but its quality is such that it can not be used satisfactorily in tubular coolers and condensers without treatment. To treat all water for a once-through system would be very costly. Therefore, the Cleveland plant uses river water treated in a clarifier for make-up to cooling towers, which in turn circulate water to tubular heat exchange equipment. Untreated river water is used, however, where it is practical to do so, as in open condenser boxes. Figure 1 is a simplified diagram of this system. A new crude unit now under construction incorporates the more efficient tubular heat exchange equipment and a new cooling tower to provide circulating water. Another clarifier is being built to supply make-up of proper quality to this new tower. When these units are completed, the refinery will be on an essentially complete circulating system, which will simplify waste treatment problems.

Lima Refinery

At Lima, the problem is one of both availability of water and pollution control. The Ottawa River is a source of water only during periods of relatively heavy rainfall. Refinery wells furnish the main portion of the water requirements, but the supply is limited. Pollution control is important because

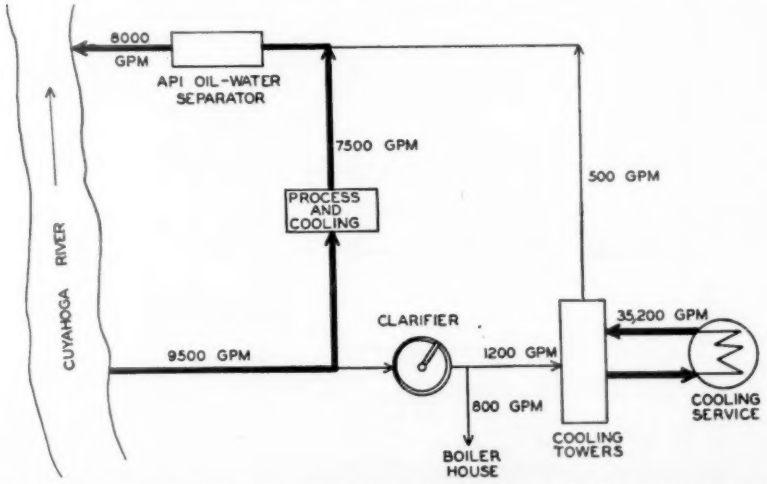

FIGURE 1.—Water system at Cleveland, Ohio, refinery of Standard Oil Company (Ohio).

in dry seasons the flow in the Ottawa River consists mainly of Sohio's effluent and the effluent from the municipal sewage treatment plant. These factors have resulted in a rather complex water system, illustrated in simplified form in Figure 2. Total water to the refinery from all sources amounts to about 4,000 g.p.m., whereas the water requirements are approximately 42,000 g.p.m. Thus, water conservation is essential from the standpoint of the availability of water alone.

Whenever it is possible to do so, soft water is pumped from the river to a soft-water reservoir of 58-m.g. capacity. This reservoir supplies 1,000 g.p.m. of water for cooling and processing, including feedwater to the boiler house. Of this 1,000 g.p.m., 400 g.p.m. of cooling water are recirculated to the reservoir for cooling and re-use. Thus, the reservoir provides for both water storage and cooling.

Eight wells on the refinery property supply 3,300 g.p.m. of cold hard water. This water is first used for cooling and condensing purposes in those services where its 55° F. temperature is most valuable. Having been used once for cooling, the well water is then used as make-up to the three large cooling towers having 40,000-g.p.m. circulating capacity. These towers supply most of the cooling and condensing requirements of the plant. Blowdown from these towers goes to a large hard-water reservoir, which provides storage and some cooling. Water pumped from this reservoir has been circulated many times, but it is used as once-through water for certain purposes before being discharged to the refinery oil-water separator.

With this system, although over 40,000 g.p.m. of water are circulated, the refinery effluent is relatively small and requires relatively small treating equipment.

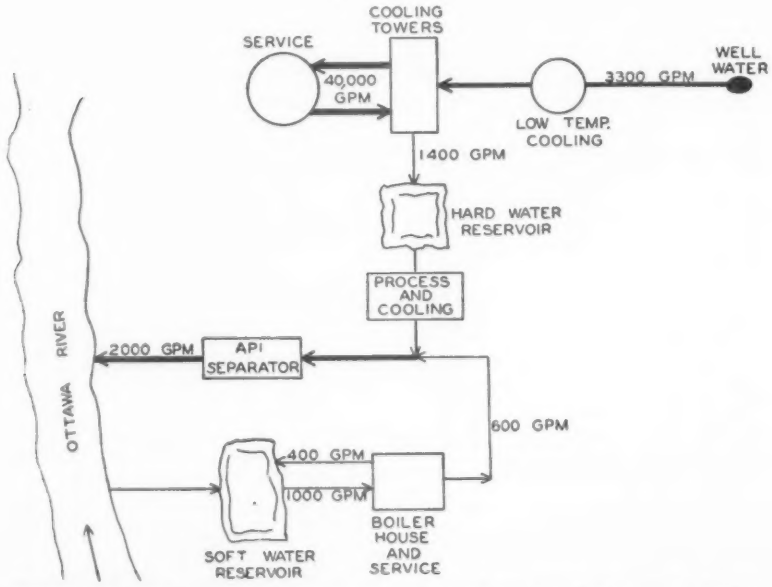

FIGURE 2.—Water system at Lima, Ohio, refinery of Standard Oil Company (Ohio).

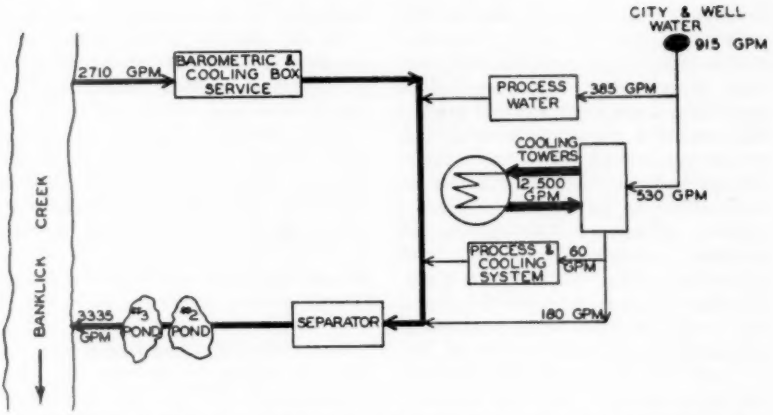

FIGURE 3.—Old water system at Latonia, Ky., refinery of Standard Oil Company (Ohio).

Latonia Refinery

The fourth refinery, at Latonia, Ky., formerly operated on a combination once-through and recirculating system. This system was the most economical in view of the high cost of city water and the limited quantity of water available from Banklick Creek. Figure 3 is a simplified sketch of the system as it was several years ago. With this system about 2,700 g.p.m. of water were pumped from the creek for once-through use. An additional 915 g.p.m. of city and well water were used, mainly for cooling tower make-up. This resulted in an effluent rate of 3,335 g.p.m.

Under these conditions, a serious pollution problem existed, particularly in the summer months. In dry periods, the quality of the creek water upstream from the refinery deteriorated and the flow dropped off to about 500 g.p.m. This meant that a large portion of the refinery water supply from the creek was actually refinery effluent being re-

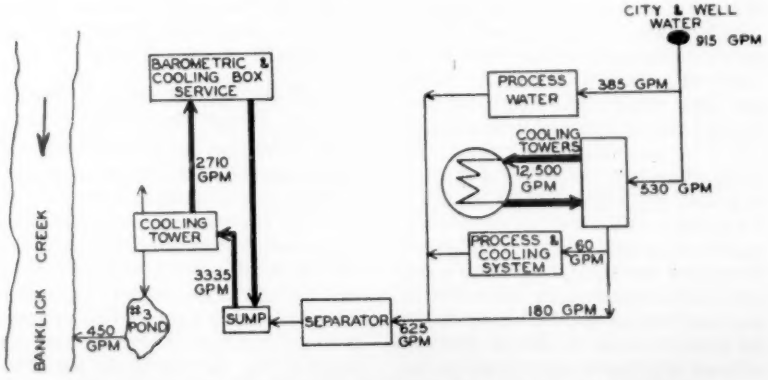

FIGURE 4.—New water system at Latonia, Ky., refinery of Standard Oil Company (Ohio).

circulated from the creek basin. The refinery effluent had a high oil content, a low dissolved oxygen content, and high temperature. This resulted in high stream temperatures and made a bad condition worse. During periods of greater stream flow, the refinery effluent had a noticeable but less serious effect on the stream. With a refinery effluent of 3,335 g.p.m., oil contents averaged 82 p.p.m., with values frequently exceeding 100 p.p.m. Dissolved oxygen averaged 2.6 p.p.m. and rarely exceeded 3.0 p.p.m. Effluent temperatures averaged 101° F. and temperatures as high as 110° F. were not uncommon.

A great deal of time was spent in studying how to alleviate the difficulties noted above. A new oil-water separator would have reduced the oil content, but would not have reduced the effluent temperatures or increased the dissolved oxygen. The obvious course of action in this case was to reduce the effluent volume and thus reduce the pollution load. Figure 4 is a simplified sketch of the present improved system.

A new cooling tower was built and added to the old creek-water circuit. This tower receives as make-up the effluent from the oil-water separator. The refinery effluent is actually the blowdown from the new cooling tower.

As a result, the refinery effluent volume has been reduced by about 85 per cent and at the same time its quality has been improved. Reduced flow through the oil-water separator has resulted in improved operation. Refinery effluent oil content now averages 52 p.p.m., compared to 82 p.p.m. before the change. Values of oil content below 30 p.p.m. are common. The reduction in oil content is appreciable, but even more important is the reduction in actual volume of oil discharged. On the basis of reduced effluent rate and reduced oil concentration, the actual discharge of oil has been reduced by more than 90 per cent. To have achieved the same reduction without reducing effluent volume would have required a separator effluent of about 6.5 p.p.m. oil, which is beyond practical limits.

The new system has also resulted in lower effluent temperatures and higher effluent dissolved oxygen contents. Table II compares the effluents from both systems. Although the increase in dissolved oxygen is not great, all factors combined have resulted in improved stream conditions.

TABLE II.—Latonia Effluent Improvement Data

Item	Old System	New System
Effluent Rate (g.p.m.)	3,335	450
Effluent Oil Content (p.p.m.)	82	52
Effluent Temp. (°F.)	101	76
Effluent D.O. (p.p.m.)	2.6	4.4

During the past year, the discharge of refinery effluent has resulted in a 1° F. rise in average stream temperature; the average upstream temperature was 58° F., whereas the average downstream temperature was 59° F. The refinery effluent has caused a reduction in dissolved oxygen from an average of 6.6 p.p.m. upstream to an average of 5.9 p.p.m. downstream. Thus, the effect of the refinery effluent upon the receiving stream has been minimized.

Water Conservation Most Important Factor

The foregoing description of the water system at Latonia serves as a good example of how pollution load can be reduced by water conservation. Other steps, such as improved housekeeping, removal of high B.O.D. materials, etc., contributed to the improvement, but the conservation phase of the program was mainly responsible for the improvements made. In the Sohio refineries, the degree of water conservation practiced is dependent upon local condi-

tions. The importance of the pollution factor is rapidly increasing. In combating serious pollution problems, an economic balance must be struck between the cost of conservation measures and the costs of effluent treatment facilities.

Cooling towers are the most practical means of conserving water through re-use, but make-up of fresh water equivalent to between 5 and 10 per cent of the circulation rate is required. Make-up and blowdown rates are of course related and depend on the amount of evaporation and windage loss, the make-up water quality, and the treatment of the circulating water. Sohio blowdown rates are usually about one-half of the make-up requirements. This fact, plus the fact that water from certain refinery uses can not be returned to cooling towers, means that there is a practical limit in the reduction of refinery effluent volume.

Costs of water conservation, particularly in changing over from a once-through system can be very expensive. Cooling towers now cost about $25 per g.p.m. of installed capacity, but added to that must be the expense of installing a whole new water return line system to complete the water circuit, and in many cases treatment facilities for make-up water must be added.

With the foregoing description of the ways in which water is used in four petroleum refineries and the reasons behind those uses, it is evident that conservation can be an important means of reducing pollution.

III. Water Conservation in a Chemical Plant

By John Ludden Jr. and John F. Vogler

Power Superintendent and Sanitary Engineer, respectively, Calco Chemical Division, American Cyanamid Co., Willow Island, Va.

An important part of effluent control is the maximum practical reduction of used-water volumes. This is especially true in the chemical industry, where some products require many gallons of water to produce a pound of finished product. Since, in general, the treatability of concentrated wastes is greater than that of more dilute effluents, and the cost of construction and operation of treatment facilities decreases with volume decreases, significant economies may be derived from reduction in the use of water. This paper is a brief account of the practical details of a water conservation propram in one plant; a program made possible by the enthusiastic cooperation of the entire plant—from the janitor to the manager.

The Calco Chemical Division's Willow Island plant is located on the West Virginia side of the Ohio River about 9 mi. upstream from Marietta, Ohio. This plant is engaged in the production of diversified fine chemical products and intermediates for the plastics, pigments, pharmaceutical, and animal feeds supplement fields. Ultimate planning calls for a considerably larger plant, in which water conservation will play a considerable part in the manufacturing economy.

Water System

Total water requirements for process, cooling, sanitary, steam, and other uses are now obtained from two 15-ft. Ranney wells extending through the gravels on the river bank to radial collectors 25 ft. below normal river level. The well water is sparkling clear, and is more constant in temperature and chemical quality than that of the ad-

jacent Ohio River, from which the aquifer receives most of its recharge. It is estimated that about 75 per cent of the well water is infiltrated from the river. There is a lag of about three months between river and well-water temperatures, and this is assumed to be the infiltration time. This lag is a fortunate phenomenon in that it provides cooler water during the hottest months and the warmer water reaches the plant after the peak of the cooling water load has been passed.

All water is chlorinated to a system residual of 0.1 p.p.m., which is the only treatment needed for most of the water. A small portion is specially treated for boiler feed-water use and for use in certain processes requiring very soft water. The well water is aggressive, due to the presence of free CO_2 and, to prevent iron contamination of the plant's products, it is distributed through an asbestos-cement underground system and cement-lined metal pipes in the buildings.

The complete water distribution system consists of three major divisions—manufacturing water, fire water, and reclaimed water, plus the soft-water system for special requirements. Three 100,000-gal. tanks, 150 ft. high, float on the soft, fire, and manufacturing water systems, respectively. At present the process, cooling, and sanitary water needs are supplied by the manufacturing water system. To date it has not been necessary to put the reclaimed water system into operation, although this system will later enable re-use of uncontaminated cooling waters for other purposes.

Effluent System

The Willow Island treatment facilities have been previously described by Vogler, Brown, and Griffin (1). The chemical waste treatment system, with which this paper is primarily concerned, consists essentially of collection of the chemical waste waters, sanitary sewage, cooling water, and precipitation runoff into a large blending and biological lagoon. Here, after 8 to 10 days of sedimentation, co-precipitation, and biological action, including considerable surface aeration, this effluent joins the effluent from the primary-secondary biofiltration plant used to treat antibiotic wastes, is chlorinated, and then flows 0.5 mi. to the Ohio River. A minimum dilution factor of more than 400 to 1 is provided by the Ohio River at this point.

In late 1950, construction of additional manufacturing facilities with larger water requirements was commenced. This caused a water conservation program to be put into effect in order that existing facilities for water supply and effluent treatment could be efficiently used and the necessary water facilities enlargements kept down to actual needs.

Basic Considerations

During 1950, the average water requirements were 3.30 m.g.d. and maximum daily pumpage was 4.53 m.g.d. Maximum firm well yield had been established as 4.60 m.g.d., with a top yield of 5.15 m.g.d. possible by overpumping the least productive well several times daily.

Increased production and expansion in 1951 were expected to increase plant water requirements to 4.6 m.g.d. (maximum firm well yield) in April and to 5.6 m.g.d. in July, with peak demands as high as 6.5 m.g.d. feared. Clearly, a potential water shortage lay ahead and prompt action was needed.

In addition to the problem of providing water for contemplated plant operation, the task of adequately disposing of larger volumes of waste was presented. In 1950 the compositing lagoon provided an average detention period of 8.3 days, gave average B.O.D. reductions greater than 50 per cent, and the plant effluent could not be detected in the Ohio River either by observation or by the routine weekly sampling program. The system was

operating efficiently, but increasing the inflows to 5.6 to 6.5 m.g.d. during the warm low-stream flow season of the year would shorten the lagoon detention period to 4 or 5 days, and probably would adversely affect its treatment efficiency. There is a scarcity of knowledge about the expected behavior of these lagoons, but it is known that holding time is an important factor in their successful operation and there was apprehension about any material reduction in retention. It became doubly important, therefore, to prevent water wastage.

Method of Attack

A thorough restudy of water production and comprehensive pump and well tests showed that the only additional water yield possible at that time would be a gain of 0.7 m.g.d. by replacing one four-bowl well turbine pump by a five-bowl installation. This was accomplished without delay. Plans were made for an increase in water supply and effluent treatment facilities coupled with an immediate and permanent water conservation program. Essentially this conservation program consisted of the following:

1. Widespread plant publicity and solicitation of cooperation by supervisory and operation personnel.
2. Review of all operations by the responsible department heads to determine minimum process requirements and enforcement of same.
3. Installation of a separate water meter for each building and establishment of a daily meter reading program.
4. Daily plant-wide water policing and inspection tours by the facilities inspector to determine and report significant sources of water wastage.
5. Weekly reports of departmental water usage, including past usage and present and past production data, to the various department heads, the Production Manager, and the Chief Engineer.

Application of Program

Propeller type meters, inserted in the main water supply riser pipes in each building, were selected as the most suitable solution of the individual building metering problem. Steel, welded, saddle-type meters were selected for this purpose, a total of seven being installed in the various buildings at an average cost of $340 installed complete. Total water use is measured by a 12-in. Venturi meter provided as original equipment when the plant was built.

As an immediate result of the institution of the water conservation program, a surprisingly large number of water wasting operations were uncovered by the critical review of operating instructions and actual observation of procedures by supervisory personnel. In a large number of cases it was found that design data and long-standing operational procedure were very wasteful of process water.

For instance, in one department it was found that adding an additional tube bundle to a column condenser and closely controlling valve openings would result in a water saving of 0.46 m.g.d., and that by using water valve settings sufficient for operational needs (usually within a fraction of a turn of the usual setting) another 0.18 m.g.d. could be saved. The tendency of operating personnel to turn all water valves to their maximum opening, regardless of needs, was found to be a major water waste factor.

In another department considerable water was saved by storing condenser waste water and later re-using it for filter press washing, by keeping water jet siphon time to a practicable minimum, and by closely controlling steam drier water. By these means water usage was reduced 0.19 m.g.d. despite a 10 per cent increase in production.

In another department close control of large water users, such as recovery column condensing water and reaction

kettle jacket cooling water, effected substantial water savings. As an example, it was found that it was common practice to open fully the 4-in. valve to a column condenser, using about 0.25 m.g.d., when a turn or two of the valve would have been sufficient. Economies in press and floor washings also effected appreciable savings.

The condensate from the production building heaters was ordinarily quenched in flash tanks containing sprinkler heads discharging 30 g.p.m. when wide open, which was usually found to be the case. Testing showed that 5 g.p.m. was sufficient discharge for efficient quenching. By partially blanking the sprinkler heads, flow was insured at the low figure and a saving of 0.30 m.g.d. resulted.

Daily patrols by the facilities inspector uncovered many examples of lavish use of bearing cooling water, wash lines, and hoses; laboratory wastage; water aspirators running when not needed; and leaky pipes, fittings, and fixtures.

Utilization of lagoon effluent instead of well water for the effluent chlorinator make-up and injector water resulted in a saving of about 60,000 g.p.d.

The twice-monthly drills required of the plant fire squad by the insurance company were scheduled on many occasions to utilize this normally wasted water for useful purposes, such as washing down dusty areas, buildings, and loading platforms. The location of the simulated fires was varied so that many drills also served to flush out dead-end mains, thus saving the substantial water quantities formerly required for main flushing.

In short, the entire plant became actively water conscious and cooperated enthusiastically in the venture. As a result many valuable water saving suggestions were received and acted upon, accomplishing additional conservation.

Consideration was given to activation of the plant reclaimed-water system if the outlined conservation program did not produce the desired effect. A large investment is represented in this system and the benefits of it would eventually be required. However, as shown later, the conservation program was successful, despite production increase, and there is still the additional safety factor of reclaimed water to fall back on when definitely needed.

Results

The results of the conservation program are summarized in Table I. Average flow in 1950 was 3.30 m.g.d., or 45 gal. per pound of finished product. In 1951, despite 27 per cent production increase, water usage was reduced to 3.01 m.g.d., or 33 gal. per pound of finished product. Also, the maximum total daily usage in 1951 was slightly less than in 1950.

TABLE I.—Comparative Water Use at Willow Island Plant for the Years 1950 and 1951

Flow	1950	1951
Maximum (m.g.d.)	4.53	4.46
Minimum (m.g.d.)	1.27	1.23
Average (m.g.d.)	3.30	3.01
Per lb. fin. prod. (gal.)	45	33

The correctness of the planning was also reflected in the effluent quality. The four hot months of 1951, from July through September, had only a total of 6.65 in. of rainfall, as compared with the 14.3-in. normal for this four-month period. In addition, the weather was hotter than normal, averaging 68° F. for the period, as compared with the normal average of 65° F. Despite these adverse conditions of drought and temperature, the plant's increased manufacturing program was accomplished without pollution of the Ohio River.

In conclusion it has been observed that a joint water conservation and

pollution control program is practical if it is based on metered facts, tact, good faith, and cooperation.

Acknowledgments

This program was successfully accomplished under the direction of J. W. Dykes, plant manager; J. F. Bourland, assistant plant manager; and B. S. Blitz, chief engineer.

Reference

1. Vogler, J. F., Brown, J. M., and Griffin, G. E., "Chemical and Antibiotic Wastes Treatment at Willow Island, West Virginia." THIS JOURNAL, **24**, 4, 485 (Apr., 1952).

SEWAGE DISPOSAL BY THE LAGOON METHOD

Successful operation of sewage lagoons by a number of North Dakota communities during the past few years has shown this method of disposal to be adequate in taking care of the needs of the small North Dakota community. In an article in the October, 1952, issue of *Official Bulletin*, North Dakota Water and Sewage Works Conference, W. van Heuvelen, Director, Division of Water Control, North Dakota State Department of Health, the experience with these units has been such that the Department now feels it can recommend and approve this type of final sewage disposal.

The initial lagoon installation was made in North Dakota in 1928. There are now 7 communities in the state that have been operating sewage lagoons. These include Maddock, Portland, Grenora, Butte, Hope, Fessenden, and New Town. Several other communities are in the planning or construction stages of using this type of disposal.

It has been recommended that cities of about 1,000 population purchase 30 to 40 acres of land at least ½ mi., and preferably 1 mi., from town. This area allows for future expansion and growth of the community. Existing lagoons have been built in 10-acre units, with the number of units needed determined by the population increments. For larger cities, units of 30 to 40 acres might be feasible.

Experience has shown that the sewage should be discharged into the center of the lagoon, slightly above the bottom elevation. This allows wind action to break up and distribute the sewage solids throughout the entire lagoon area and prevents them from piling upon the lagoon dike, where they would become septic and create nuisance conditions.

Existing lagoons are operating with very little or no odor and could be placed close to habitation without nuisance. Good practice, however, dictates that the lagoon should be at least ½ mi. from town or any adjacent farm buildings, so as to preclude any possibility of contaminating private water supplies.

It appears that 3 to 5 ft. is the optimum water depth. This allows good mixing by wave action, which would not be obtained in deeper water, but is deep enough to prevent difficulties with ice formation. Shallow marginal areas and emergent vegetation should be eliminated. The lagoons can be of any shape to fit the contour of the land, but should be designed to permit a maximum of wind action.

Proper lagoon maintenance requires adequate fencing to keep out animals (they break and loosen the dike material), mowing of weeds on the dike (so as not to cut down wind action), and frequent inspection for structural failures of the dikes (usually due to washouts and burrowing animals).

Tests at the Maddock lagoon show 65 per cent B.O.D. removals in winter and 95 per cent B.O.D. removals in summer. Disintegration of the sewage solids apparently is nearly complete, as the Fessenden lagoon has been in operation for 24 years without appreciable decrease in capacity or efficiency of seepage rates.

TREATMENT AND RE-USE OF WATER IN BEET SUGAR MANUFACTURING*

By George S. Fleming

Superintendent, Buckeye Sugar Company, Ottawa, Ohio

Sugar beets are grown by about 80,000 farmers in 22 states and provide about one-fourth of the sugar consumed in the United States. The 19 beet sugar processing companies own 80 factories in 16 states, having a daily slicing capacity of 148,350 tons of beets. Colorado leads the field in the number of factories with 16, and Michigan is second with 13 factories. However, California, with 11 factories, has a much larger daily capacity in tons of beets sliced.

In 1950, 924,000 acres of beets were harvested in this country with an average yield of 14.2 tons per acre, which gave 37,383,000 100-lb. bags of sugar.

Our Buckeye Sugar Company plant in Ottawa is one of three in Ohio, the other two being in Fremont and Findlay. It has a slicing capacity of 1,000 tons of beets per day.

Extraction Process

The process of extracting sugar from beets is essentially chemical. The beets are first piled over a flume and then floated into the plant, where they are washed, picked over, and raised by an elevator to a weighing hopper. They are then dumped into slicers, where they are cut into V-shaped ribbons called "cossettes." These cossettes are then fed into the diffusion battery, consisting of 14 bottom-dump cells or vats holding approximately 3 tons. Hot water is introduced into the cell that has the most nearly exhausted cossettes and passes progressively through the battery to the cell containing the fresh cossettes, where it is drawn off as a diffusion juice. Through this countercurrent flow, the fresh water comes in contact with the cossettes with the lowest sugar content and serves to remove the greatest amount of sugar possible from the beet. After all the sugar has been extraced from the cossettes, they are dumped into the battery pulp pit and pumped to pulp screens. The screened pulp is pressed and then dried in rotary driers to produce a high-grade cattle feed.

The diffusion juice then enters the first carbonation tank, where milk of lime is added, followed by the addition of carbon dioxide gas. The combination of lime and carbon dioxide forms calcium carbonate, an insoluble precipitate, which removes the impurities from the juice. The mixture is then overflowed to a 5-tray thickener. The sludge is pumped from mud trays to vacuum filters, where the washed lime cake is diluted and pumped to a lagoon (see Figure 1). The clear effluent juice is then filtered through plate and frame presses and sent to a second carbonation unit, where carbon dioxide is again added to precipitate any of the lime remaining in the press juice. After another filtering, sulfur dioxide gas is added to adjust the pH and alkalinity. After the addition of SO_2 the juice is filtered a third time and goes to evaporators, where a heavy syrup containing 50 to 60 per cent sugar is produced.

The thick syrup goes to the melters, where melted sugar is added, and then pumped through another set of filters

* Presented at 26th Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conf.; Toledo, Ohio; May 21–23, 1952.

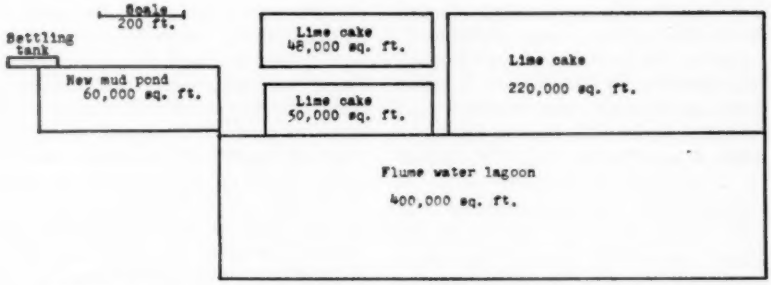

FIGURE 1.—Layout of impounding reservoirs for beet sugar factory wastes, Buckeye Sugar Co., Ottawa, Ohio.

to the vacuum pans, where it is boiled and crystals of the desired size are formed. When crystallization is complete the mixture is dropped into centrifugal separators where the syrup is spun away from the crystals through a fine-mesh screen. The remaining crystals of pure sugar are washed, dried in granulators, and sacked.

As previously stated, the Ottawa factory has capacity for slicing 1,000 tons of beets per 24 hr. In addition, 50 to 60 tons of limerock, 5 to 8 tons of coke, and approximately 150 tons of coal are used per 24 hr. The old saying that it takes 1 lb. of coal to produce 1 lb. of sugar is a little out of date, as the plant is doing a little better than that under present operations. Another interesting item is that it takes 1,000 to 1,250 gal. of water to produce a 100-lb. bag of sugar. The Ottawa plant produces 2,500 to 3,000 100-lb. bags of sugar, 1,000 to 1,200 100-lb. bags of dried beet pulp, and approximately 50 tons of molasses per 24 hr.

History of Problem

Beet sugar waste disposal is a problem as old as the industry itself. And since beet sugar processing is of seasonal duration and the operation of the factory produces some rather objectionable wastes, especially in October, when the streams are at their lowest, the industry has frequently been the target of pollution control investigations.

The plant under discussion has been no exception. Ever since the factory was built in 1912 the owners have been working on the waste problem, mostly from a standpoint of stream pollution control. The records show that the Ohio Department of Health received the first complaint pertaining to the factory a few years after it was put in operation. The seasonal character of the waste problem imposes several limitations from an economic point of view on possible methods of waste treatment. During the early years several methods were tried to control the waste, but without much success. In 1936, the Ohio Sugar Company, predecessor of the present company, came to the conclusion that the re-use of waste waters was the most satisfactory and least expensive solution to the problem. During 1937 and 1938 the company spent considerable money installing additional valves and piping on the diffusion battery, and in setting up two rotary mechanical screen filters for the purpose of re-using process water. This system had been used with some success in German sugar factories, but failed to work out with much satisfaction here. Then, in 1939, the company installed equipment to re-use and recirculate the beet flume water, and a spray pond for the aera-

tion and cooling of condenser water before discharging it into the river.

During the next eight or nine years, with time out for World War II, additional equipment was installed and changes were made in piping and tanks in an effort to control the waste. It is felt that in the past few years results have been accomplished that will lead to complete control of the plant's industrial waste; in other words, no objectionable waste will be discharged into the Blanchard River from the plant.

Waste Characteristics and Recovery

There are five kinds of objectionable wastes produced by beet sugar refineries, as follows:

1. Flume water, used for washing the beets and transporting them from the stockpile into the factory.
2. Process water, consisting of the battery wash, which results from the operation of flushing the exhausted cossettes from the diffusion battery, and the pulp press water resulting from the partial dewatering of the exhausted pulp.
3. Lime cake, the residue from the carbonation process.
4. Condenser water from evaporators, vacuum pans, etc.
5. Steffens waste, resulting from additional extraction of sugar from molasses.

Flume Water

The flume water, consisting of the transport water and the water used in the beet washer, is a large-volume waste. In has a high suspended solids content of essentially dirt, sand, and debris, but its characteristics depend considerably on the nature of the weather during harvest and the extent of beet spoilage in the stockpile. Measurements made at other factories show that the mud discharged, exclusive of lime cake, ranges from 6 acre-ft. at small factories to as much as 23 acre-ft. per year at plants such as Billings, Mont., where there is a daily slicing capacity of 3,500 tons of beets. Great variations in these quantities from year to year are, of course, to be expected. With more and more mechanical beet harvesters used in the fields, the mud problem will increase. In the past years the suspended solids in this waste show a considerable increase. In 1946 the suspended solids of the flume water was 800 p.p.m., and in 1949, a wet year at harvesting time, the suspended solids in the influent to the clarifier jumped to 3,170 p.p.m. In 1950 there was better weather, but the suspended solids still averaged 2,000 p.p.m. The B.O.D. of this water has increased with the amounts of solids. In 1946 the B.O.D. was 200 p.p.m., which has increased to 1,312 p.p.m. in 1950. The population equivalent of the waste is 20.2 per ton of beets, or 20,200 for the 1,000-ton plant.

To handle this large-volume waste an attempt is being made to re-use and recirculate and hold it in a closed circuit so that none is discharged to the river. The original equipment installed in 1939 to accomplish this end has not proven adequate and additions and changes have had to be made.

Methods of handling our flume water at present are as follows:

The water as it circulates in the system is first chlorinated; hourly tests keep the residual at approximately 0.11 to 0.15 p.p.m. This kills bacteria and controls odors; which so far is a condition that has not been objectionable. The water next enters a receiving well having a capacity of 10,000 gal., where it is circulated to a settling tank by two 3,000-g.p.m. pumps. The settling tank has a capacity of 88,400 gal. and is equipped with chain drag and sludge pump. The 30-min. detention period of this tank is only one-half enough for the volume and condition of the water. The most recent tests showed a suspended solids re-

moval of only 46.2 per cent, which is quite a drop from the 87.1 per cent removal when originally installed. A plunger pump in the tank delivers mud to a pond at the rate of approximately 150 g.p.m. The effluent from this tank goes directly into the beet flumes to wash the beets into the factory. There are 17 of these flumes 400 ft. in length.

There has been installed in the header flume a mechanical weed catcher that drags the flume just before the beets enter the house. This device does a good job of picking out beet tops, weeds, etc. In this same circuit and just after the beets are washed there is a screen of the drag type with 1/32-in. slotted openings. This screen and drag take out all the pieces of beets and trash from the washer and picking table, the debris being scrolled outside the factory, where it is loaded onto trucks and hauled away. This returns the water back to the point where it is chlorinated for recirculation.

This circuit sounds simple enough, but due to the uneven fluming, the large amounts of beets falling into the flumes, and the inability of the factory to take exactly the same amount of beets each hour, large volumes of water enter the receiving well intermittently. That water must go somewhere and if the equipment will not handle it—in the present case it will discharge into the river and the system is no longer a closed one. To handle this surge, which amounts to 309 g.p.m. (as calculated in a 1950 survey), additional receiving well capacity was installed along with a second 3,000-g.p.m. pump, with two pipelines to the settling tank. However, it has been found that the settling tank cannot take care of this excess water.

In the summer of 1952 a new 6-in. pipeline is to be laid from the settling tank so that any extra water can be pumped into a retaining pond or lagoon, where it will be held until the river is high enough to handle the extra pollution load with little or no effect. This lagoon will have an area of 400,000 sq. ft., which should be large enough to handle the extra water for the entire season. An additional mud jack is being installed in the settling tank to pump the mud into a new mud pond being built adjacent to the tank. This will eliminate the friction problem in pumping a sludge through a long pipeline as heretofore in use. The new mud pond will have an area of 60,000 sq. ft. Any overflow from the settling tank will flow into a sump and be pumped to a lagoon.

Process Water

Process water refers to the water used to extract the sugar from the cossettes, battery wash water, and pulp press water. In most factories the latter two components are allowed to flow to the sewer and form one of the most objectionable wastes of the industry. The volume of process waste water may vary from 300 to 500 gal. per ton of beets processed. Numerous attempts have been made by the beet sugar industry to treat and re-use the process waste water, but not until 1948 was the solution found in the chlorination of this water for re-use. Much of the plant testing of the method was done in the Ottawa plant, and before the end of the season 75 per cent of the water was being returned to the battery and re-used without any ill effects to the process.

In 1949, the company purchased a chlorinator and a lime feeder and set out to re-use the entire waste. The project was initiated with some misgivings, but with a determination to either make the process work or throw it out and forget it. Just as soon as the tanks filled up and figures were obtainable on the chlorine residual and pH, all the water was returned to the battery and to the process. The solids kept building up, which threw quite a scare into all concerned, but the water was continuously recirculated. The

total solids built up to 13,000 p.p.m. and then tapered off, never going any higher; then held an average of about 9,000 p.p.m. total solids and 6,032 p.p.m. dissolved solids. These values are enough to turn any sugar man's hair grey, as a 2,000-p.p.m. value on total solids used to be something to get alarmed about.

The results, however, are proof of the efficacy of the process. The Ottawa plant has been operated for three full seasons re-using the entire amount of process waste water with no actual ill effects to the making of sugar.

To briefly describe the method of re-use; the water from the battery pit (where water and exhausted beets are dumped) is screened off and the beet pulp is conveyed to the pulp presses. The screened water drops into a 2,200-gal. tank, where it is chlorinated and limed. The lime controls the pH near the desired 7.0. Over the last three years the chlorine residual has averaged between 0.25 and 0.30 p.p.m. About 300 lb. of chlorine are used per 24 hr. After the water has been chlorinated and limed, it is pumped into a second 2,200-gal. coagulation tank and then pumped into a 6,000-gal. three-tray settling tank. All these tanks are cone-bottomed and the sludge is constantly being pumped off into two mechanical rotary-screen type filters. The effluent from the last tank flows directly to the battery supply tank, where it is mixed with condenser make-up water and pumped back to the battery. The pressed pulp water, which is really the most objectionable portion of the process water, is returned to the battery pit and is re-introduced to the process through this channel.

Approximately 420,000 g.p.d. (300 g.p.m.) of water is circulated through the three tanks, giving a detention period of about 35 min., which is not quite long enough. This brings out the only fault to be found with the equipment; more settling time is needed, or equipment that will enable return of a better water to the battery. However, the plant has been operating very satisfactorily with the present equipment and the only overflow or waste from this system goes directly into the flume circuit.

It has been estimated that as much as 40,000,000 lb. of sugar a year could be saved using the recirculation process in the industry. However, that wouldn't all be the familiar granulated variety that could be bagged and sold. Much of the salvaged sweet stuff would end up as higher sugar content in molasses and feed for livestock which pour out of the refineries as by-products. The experts also calculate the water saving might reach 3,000 m.g. per year, as the waste liquid, once treated, could be used over again.

This all sounds very encouraging and a little fantastic at present, as the process has not yet reached that point of development. Some have set the profit for any sugar factory using the process at $8,000 per year, others have predicted a saving of 4 lb. of sugar per ton of beets. This would amount to $21,600 on a 60-day run for the Ottawa factory. These figures are also a little fantastic. Actually, on the basis of operations at the Ottawa plant, the data of Table I are more applicable. With three years of extraction and operating data and the company's experience with the process, the calculations of Table I are believed to be more nearly representative.

It will be noted from the information presented that there is actually a decrease in the granulated in the bag, but an increase in the molasses production. This is true because for each pound of non-sugars introduced into the process 1.5 lb. of sugar is lost in molasses. As long as the molasses market price remains where it is ($48.00) the plant can manage, but it will certainly go into the red if the market drops. Here again if there were available a good means of filtering or settling the process water without installing elaborate equipment, a bet-

TABLE I.—Evaluation of Re-Used Water System for Battery Supply, Buckeye Sugar Company, Ottawa, Ohio

Dissolved solids, total[1]	6,032 p.p.m.
Sugar content[2]	4,567 p.p.m.
Purity	75.71%
Total non-sugars	1,465 p.p.m.
Non-sugars through defecation (75%)[3]	1,099 p.p.m.
Average sugar in pulp water (straight house)	1,300 p.p.m.
Basis of 50,000 tons of beets	
Non-sugars	109,900 lb.
Sugar lost with non-sugars (60 purity molasses)	164,850 lb.
Normal loss in straight house (savings)	130,000 lb.
Sugar make-up from granulated	34,850 lb.
Balance	
Loss in granulated @$0.09/lb.	$3,136.00
300 lb. per day chlorine (50 days @$0.1025/lb.), plus freight	1,578.00
Labor 3 men, 50 days @$1.12/hr	1,344.00
Depreciation on $10,000 equip., 10 years	1,000.00
Total	$7,058.00
Increase in granulated (loss, as above)	0.00
Increase in molasses (55% sugar) @ $48/ton	7,173.00
Net profit[4]	$ 115.00

[1] From Ohio Dept. Health tests made Nov. 15–17, 1950.
[2] From company laboratory sheets.
[3] Great Western Sugar Co., "Technology of Beet Sugar Manufacturing."
[4] Not including maintenance to equipment.

ter water could be returned to the battery and eliminate much of the suspended matter and possibly some of the murky color. This in turn would give better battery diffusion and better juice. It probably is because of the high solids and color problem that the majority of the large factories in the West feel a little reluctant about using the process. However, chlorination and re-use of this waste water can be worked out to advantage both from the standpoint of sugar processing and elimination of stream pollution.

Lime Cake

The lime cake problem is of minor importance because all this waste is diluted to a slurry and pumped to a lagoon. The volume of this waste amounts to about 150 gal. per ton of beets. The Ottawa plant has two large lagoons for this purpose, neither of which is ever discharged to the river. Use of these lagoons is alternated; as one is being used the other is drying out. When possible, the dried cake is loaded and given to farmers for fertilizer.

This waste is strong and would be very detrimental to any receiving stream. Total solids run 200,000 p.p.m., with an average B.O.D. of 10,200 p.p.m. But, as mentioned, none of this is ever discharged to the river.

Condenser Water

The evaporator condensing water as a rule is not considered as an industrial waste. Its oxygen-demanding capacity is generally determined by the amount of carryover and vapor entrainment, which depends on operating conditions and the efficiency of the equipment employed. One significant objection to the discharge of this waste is its relatively high temperature. This objection has been overcome at Ottawa by installing a spray pond to aerate and cool the condenser water before discharging into the river. The equipment includes two tanks, two pumps controlled with float switches, and two sets of spray nozzles consisting of 14 each. The volume is approximately 1,400 gal. per ton of beets. The B.O.D. will vary, but the average is approximately 50 p.p.m.

The raw water is chlorinated as it enters the factory. In addition to preventing bacterial growth, it has been noticed that chlorination keeps the condensers free of scale. This year a 6-in. pipeline also has been installed from the vacuum pan seal tank to the intake reservoir. This will serve to return a good head of condenser water back to

the reservoir for re-use. There is a possibility that during seasons of low water in the river the company may find it advisable to set up a series of sprays over the intake reservoir and re-use more of the condenser water.

However, if the vapor entrainment of this waste can be cut to a minimum and all other factory wastes can be prevented from contaminating this water, the Health Department should have no objection to this aerated waste being returned to the river.

Steffens Waste

The Ottawa plant is not concerned at present with Steffens waste, as the Steffens house is no longer operated at this location. Due to the high price of molasses it is doubtful if that part of the plant will be operated again. In those plants having this waste, however, its control through use in the manufacture of glutamic acid is a very interesting subject.

Summary

It readily can be seen that the waste disposal problem of the Ottawa beet sugar refinery is complicated by wastes of large volume and high solids and organic characteristics produced, during short seasonal operations of 50- to 80-day duration, in the fall of the year when the receiving streams are very low.

The total discharge averages 2.88 m.g.d., with an average B.O.D. of 213 p.p.m.

If all five of the objectionable wastes were held within closed circuits, with the exception of the aerated condenser water, the total discharge would be 2.636 m.g.d. carrying a B.O.D. of approximately 50 p.p.m. The average B.O.D. of the Blanchard River at the plant intake is about 35 p.p.m.

Acknowledgments

Considerable help and information concerning the problem discussed herein has been given by the Sanitary Engineering Division, Ohio Department of Health, under the direction of B. M. McDill. Acknowledgment is also made of the help given by H. H. Black and Paul Agnano of the U. S. Public Health Service Environmental Health Center, Cincinnati, Ohio.

DETERMINATION OF PHENOLS BY THE p-NITROSODIMETHYLANILINE METHOD

By Robert H. Hill and L. K. Herndon

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For some time there has been a need for a phenol analysis which is rapid, accurate, sensitive, and free from interfering compounds. Recently this has become more urgent, for pilot plant and laboratory studies on phenol removal require a rapid analysis to provide information for subsequent treatment. The method should also be sensitive in the low phenol concentration range, as chlorophenols give water an unpleasant taste in concentrations of 5 to 10 p.p.b.

The literature was reviewed, and preliminary tests were made on several methods of phenol analyses. As a result of these studies it appeared that a method based on the reaction of p-nitrosodimethylaniline with phenol offered some unique advantages. This reaction was first developed by Houghton and Pelly (1) in 1937. No published literature has since been found on the evaluation of this method for phenol analysis. These authors stated that the color developed in 10 to 20 min. and was sensitive to 10 p.p.b. phenol. They also reported that the only other compounds which reacted with this reagent were primary aromatic amines such as aniline, toluidine, and xylidine. It was found that the interference of these compounds could be eliminated by distillation in the presence of excess sulfuric acid and then buffering the sample to a pH of 8.5 to 9.0. Strong oxidizing and reducing agents also interfere if no preliminary treatment is used for their removal.

In the method as outlined by Houghton and Pelly, the procedure was as follows: a 100-ml. sample containing 0.1 to 0.4 p.p.m. phenol was buffered with 2 ml. of 5 per cent $NaHCO^3$. To this, 2 ml. of a 0.1 per cent solution of freshly reduced diamine reagent was added. This solution was then titrated with a 0.05 per cent available chlorine solution until the pink color just disappeared and a blue color formed. The sample was then compared in Nessler tubes with standards prepared at the same time.

In phenol concentrations below 0.1 p.p.m. or 100 p.p.b. they recommended using 200-ml. samples. The amounts of buffer and reagent were likewise doubled. The color formed by titrating with 0.05 per cent available chlorine solution was then extracted twice serially with 20 ml. of carbon tetrachloride each time. The extracts were then combined and compared with standards.

The purpose of the present paper is to present additional information on the use of p-nitrosodimethylaniline as a reagent for rapid and sensitive phenol analysis.

Optimum Condition of Analysis

Figure 1 shows the effect of pH on color intensity of phenol and aniline samples. The pH values given previously were taken before the addition of the hypochlorite solution. The final pH was increased by 0.3 to 0.5 upon adding this reagent. In order to reduce the interference of primary aromatic amines it is recommended that the pH of the sample be 8.3 to 8.7 before the final addition of the hypochlo-

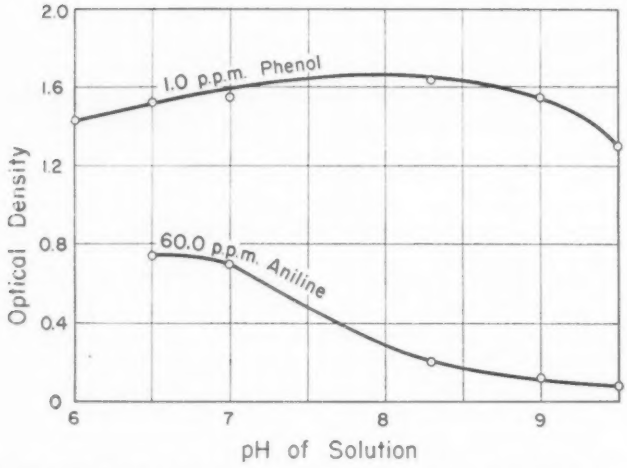

FIGURE 1.—Effect of pH on color development; Evelyn colorimeter, 660 mμ.

rite solution. A 5 per cent $NaHCO_3$ solution is a good buffer in this range. When the samples are not difficult to buffer, 5 ml. of the $NaHCO_3$ solution should be used for each 100 ml. of sample. If the sample is first distilled in the presence of H_2SO_4, 10 ml. of buffer should be added for each 100 ml. of sample.

In Method I, in the high concentration range, 2 ml. of 0.1 per cent diamine reagent is best. From Figure 2 it appears that 4 ml. or 5 ml. is optimum, but it was found that more reproducible results could be obtained using 2 ml. This is probably due to less interference from the reagent itself.

In the low concentration range, where 200 ml. of sample is used, 4 or 5 ml. of 0.1 per cent reagent was considered best from both the standpoint of results and from the information obtained from Figure 3. The optimum

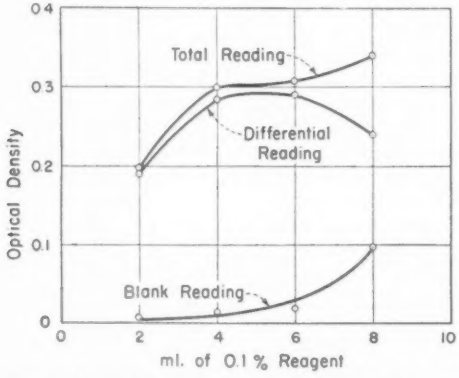

FIGURE 2.—Reagent requirements for 100 ml. of aqueous solution containing 1.0 p.p.m. phenol; Evelyn colorimeter, 660 mμ.

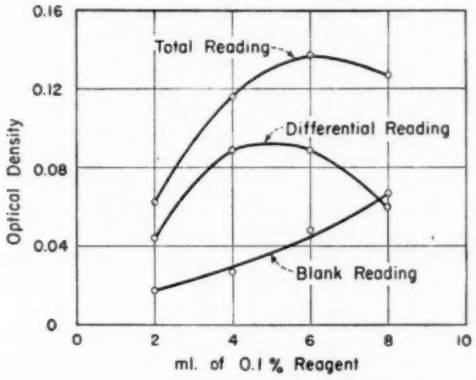

FIGURE 3.—Reagent requirements for Method II, 50-p.p.b. sample, iso-amyl alcohol extraction; Beckman, 610 mμ.

amount of reagent apparently depends upon the sample size; that is, 2 ml. for each 100 ml. of sample.

The amount of hypochlorite solution to add is determined by titrating until a blue color appears. The first color formed is pinkish, but this changes to a deep blue on phenol samples above 0.1 p.p.m. On samples containing less than 0.1 p.p.m. or 100 p.p.b. the hypochlorite solution is added until the pink color completely disappears. Each sample in the concentration range of 0.1 to 1.0 p.p.m. should be titrated. In the lower concentration range, each sample may be titrated or

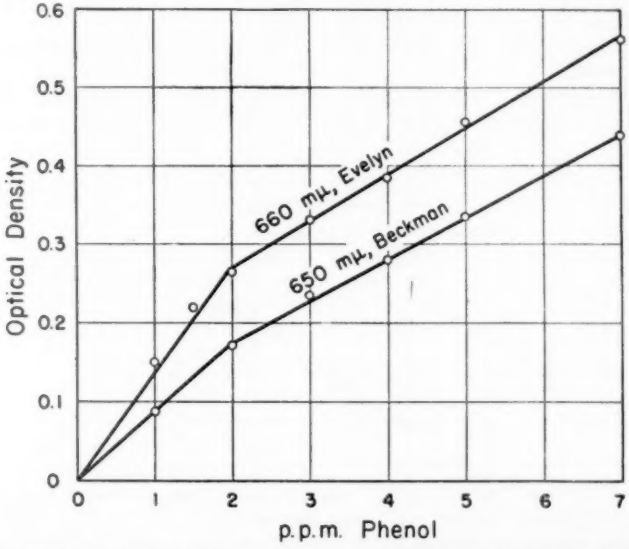

FIGURE 4.—Standard calibration curve for phenol determination, Method I.

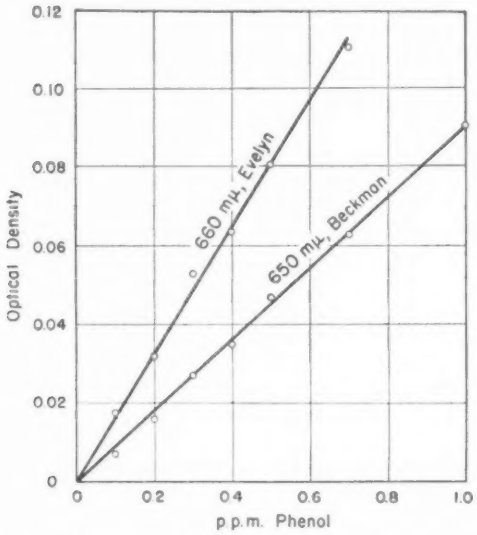

FIGURE 5.—Standard calibration curve for phenol determination, Method II.

a definite amount added as already predetermined on one sample in this lower range. The hypochlorite solution may contain either 0.05 per cent or 0.1 per cent available chlorine. A solution of 0.05 per cent available chlorine is preferred, however.

For precise results a blank should be run with each series of samples analyzed. This blank contains phenol-free water plus all the reagents, including the hypochlorite solution. The blank is stable and gives only a slight color.

The color intensity increases with time very slowly. The most suitable length of time was selected to be from 15 to 30 min. It doesn't actually make

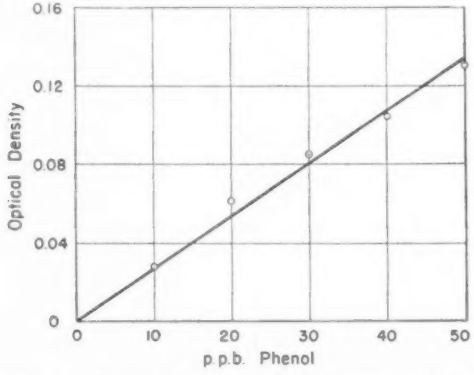

FIGURE 6.—Standard calibration curve for phenol determination, iso-amyl alcohol extraction; Beckman, 650 mμ.

much difference as long as the color of the standard, unknown, and blank samples are allowed to develop for the same length of time.

Iso-amyl alcohol is better than carbon tetrachloride or chloroform as an extracting reagent, as the extracts are more stable. Color extracts of iso-amyl alcohol are stable for at least 1 hr. if kept out of strong sunlight. The color intensity is also greater in extracts of iso-amyl alcohol.

Carbon tetrachloride and chloroform are good extracting reagents if the colors are compared visually in Nessler tubes, but should not stand more than 15 to 30 min. before comparisons are made.

Standard Graphs

Standard curves of optical density *vs.* phenol concentration are obtained in three concentration ranges: (a) from 5 to 50 p.p.b. (0.005 to 0.05 p.p.m.), (b) from 0.1 to 1.0 p.p.m., and (c) from 2 to 7 p.p.m. These results are shown in Figures 4, 5, and 6. The phenol samples were prepared in distilled water. Within these concentration ranges a straightline relationship is obtained with both the Evelyn filter photometer and the Beckman spectrophotometer. The optimum wave length is found to be 650 mμ. on the Beckman spectrophotometer, whereas on the Evelyn colorimeter a filter with a wave length of 660 mμ. gives suitable results. The best wave length for the iso-amyl alcohol extracts is 610 mμ.

It is noticed that the slope of the line changes on the plot in the phenol concentration range of 1.0 to 7.0 p.p.m. There is a definite break in the line at 2.0 p.p.m., with the slope at a much lower value than that from 0.1 to 1.0 p.p.m. This break appears in all of the graphs obtained and could be caused by some difference in the reaction between these two concentration ranges. The color difference between these two ranges can easily be observed with the naked eye. This phenomenon will not cause difficulty in analysis as long as the standard samples are below 1.0 p.p.m. Above 2.0 p.p.m. two standard samples must be used, as the line does not go through the origin.

With all of the foregoing analyses, a blank with the reagents added to distilled water is used for a zero setting on the instrument. Special precautions have to be taken in order to obtain phenol-free water in the phenol concentration range of 5 to 50 p.p.b. This is done by percolating distilled water through a bed of activated carbon 4 in. thick. This water is then re-distilled to remove traces of activated carbon filtered into the water.

Sensitivity and Reproducibility

The sensitivity of this method is approximately 5 p.p.b. This value is nearly the same if the color is extracted with iso-amyl alcohol and compared on a spectrophotometer as when the extraction is performed with CCl_4 and compared with Nessler tubes.

The average deviation, or mean error, was calculated for each concentration range. These values were obtained by noting the deviation from the best straight line. From 2 to 7 p.p.m. phenol the mean error, or average deviation, was ± 0.07 p.p.m., based on 17 points. In the concentration range of 0.1 to 1.0 p.p.m. the average deviation was ± 0.011 p.p.m., based on 30 points. Ten analyses were taken of the iso-amyl alcohol extracts in the low p.p.b. range, which gave an average deviation of ± 2.0 p.p.b. With the use of Nessler tubes the extracts of CCl_4 were compared in the range of 5 to 50 p.p.b. and the average deviation of 18 points was ± 2.0 p.p.b., using standards which were 5 p.p.b. apart.

Other Phenol Compounds and Some Possible Sources of Interference

If an unknown sample contains m- or o-cresol there is only a maximum error of 10 per cent, whereas in most

TABLE I.—Some Compounds Compared With Phenol

Compound	Phenol Type % of Phenol	Non-Phenol Type % of Phenol
Phenol	100.0	—
O-cresol	110.0	—
M-cresol	92.0	—
P-cresol	3.7	—
α naphthol	7.6	—
Catechol	4.0	—
Resorcinol	0.6	—
Thymol	4.0	—
Hydroquinone	0.6	—
Aniline	—	1.4
Aniline[1]	—	0.2
O-toluidine	—	2.4
Salicylic acid	—	0.0
Formaldehyde	—	0.0
Benzoic acid	—	0.0

[1] Aniline sample distilled in presence of excess H_2SO_4 (4 ml. of concentrated H_2SO_4 in 220 ml. sample).

other known methods the error is much greater due to the difference in color intensity of phenols and cresols.

P-cresols give only 3 per cent as intense a color as phenol, as shown in Table I. This is approximately the same intensity as with other colorimetric methods, since p-cresols do not tend to couple to form the colored compounds.

Other phenol-type compounds give a much lower color intensity than does phenol, which is characteristic of several colorimetric phenol analyses. It is generally agreed that the chlorinated phenols and cresols are the worst taste offenders, but no comprehensive study has been made on this subject. Thus, it is not known whether or not a phenol analysis should quantitatively determine all phenol types.

Table I also shows that aldehydes and organic acids do not interfere in the test. Aniline and o-toluidine as well as other primary aromatic amines will interfere to a slight degree if no precautions are taken. It is also shown in the same table that the influence of these compounds can practically be eliminated if distilled in the presence of 2 ml. of concentrated H_2SO_4 for every 100 ml. of sample. Under these conditions, a 100-p.p.m. aniline sample gives a color intensity equivalent to 0.2 p.p.m. phenol.

Analyses on actual trade wastes from coke plants, creosote factories, and refineries show that the modified Houghton and Pelly method gives results consistent with other methods, as shown in Table II. Refinery waste samples or any other samples containing a large amount of sulfides should be first distilled in the presence of $CuSO_4$.

TABLE II.—Results of Phenol Analyses of Trade Waste Samples

Waste, p.p.m. Phenol	Method[1,2,3]								
	Houghton and Pelly (1)		Gibbs (2)		Nolte (3)		Knowlton (4)		Dannis (5)
	D	ND	D	ND	D	ND	D	ND	D
Creosote waste	208[4]	208[4]	200[4]	200[4]	—	200[4]	220	N. G.	—
Industrial coke oven waste, S-1	112	—	100	100	80	200	110	N. G.	116
Industrial coke oven waste, S-2	—	170	166	166	150	300	183	N. G.	170
Refinery waste	266	N. G.	250	N. G.	625	1250	315	N. G.	268

[1] Figures in parentheses denote literature references.
[2] D means that the sample was first distilled by the Gibbs procedure before being analyzed; ND means that the sample was analyzed without distilling.
[3] N. G. means "no good"; that is, results could not be obtained due to interfering compounds.
[4] 50-50 mixture of phenol and o-cresol used as a standard.

The method by Nolte (3) is performed by coupling diazotized p-nitroaniline with phenol to produce a red-colored complex. In Knowlton's (4) method the phenol is brominated under carefully specified conditions. The excess bromine liberates iodine, which is titrated with a thiosulfate solution. In the method described by Dannis (4), 4-aminoantipyrine was used.

Recommended Procedure

Method I—Phenol Content >100 P.P.B.

1. Prepare three 100-ml. samples—one with phenol-free water for blank, one with 0.5 p.p.m. phenol as a standard, and the other the unknown sample, with the phenol concentration diluted to 0.1 to 1.0 p.p.m.

2. Add 5 ml. of $NaHCO_3$ solution to 100 ml. of sample in a flask.

3. By pipetting, add 2 ml. of the filtered diamine reagent which has been freshly reduced.

4. Then run hypochlorite solution in gradually from the burette with gentle agitation. The first addition of the hypochlorite solution results in the formation of a pronounced pink color, but this goes away, and the solution changes to pure blue. (This shouldn't be overtitrated any more than necessary; that is, 0.5 ml. or less does not interfere in the test.)

5. The optical density of the standard and the unknown is obtained on a spectrophotometer using the blank as 100 per cent transmission or 0.0 optical density. When a spectrophotometer is used, the optimum wave length is 650 mμ. A filter photometer also may be used with an appropriate filter. The phenol concentration in the unknown sample is calculated from a simple proportion, as the relationship is linear.

Method II—Phenol Content 5 to 100 P.P.B.

1. Prepare three 200-ml. samples—a blank, a 50 p.p.b., and an unknown. The standard sample and blank should be made with water that has been percolated through activated carbon and then re-distilled. This treatment is not necessary if the blank is almost water-white in color.

2. Add 5 ml of $NaHCO_3$ solution followed by 4 ml. of the freshly reduced diamine solution to 200 ml. of sample in a separatory funnel.

3. Add the correct amount of hypochlorite solution so as to just discharge the pink color which first appears.

4. Extract the samples with 10 ml. of iso-amyl alcohol. The extraction is repeated with 5 ml. more of the iso-amyl alcohol. The extracts are then combined and made up to 10 ml. in a glass-stoppered cylinder. This is possibly due to some solubility of the alcohol in the water. To the extracts, add a small amount of anhydrous Na_2SO_4 to remove any water present.

5. The extracts of the known and unknown samples are then compared against the blank on the spectrophotometer or the filter photometer. The optimum wave length on the spectrophotometer is 610 mμ. The phenol concentration is determined as before, using linear proportion between optical density *vs.* p.p.b. phenol.

Method III—Phenol Content 5 to 100 P.P.B.

1. To a 500-ml. sample in a separatory funnel add 8 ml. of $NaHCO_3$ solution followed by 8 ml. of the freshly prepared diamine solution.

2. A 0.05 per cent hypochlorite solution is added gradually with shaking until the pink color just disappears.

3. The color is allowed to develop for 15 to 20 min., then the samples are extracted serially twice with 20 ml. of CCl_4 each time.

4. The extracts are combined and dried with a little anhydrous Na_2SO_4. They are then poured into the 50-ml. Nessler (tall type) tubes, diluted up to the mark, and compared with standards immediately.

Special Equipment and Reagents

The special equipment and reagents needed in the p-nitrosodimethylaniline method include the following:

1. A spectrophotometer or filter photometer. A Beckman spectrophotometer Model DU was used in this work, along with an Evelyn filter photometer.
2. A pH meter.
3. A pyrex all-glass distillation apparatus provided with a Graham condenser, to be used if distillation is found to be necessary.
4. Ground-glass stoppered graduates, 10-ml. size.
5. A 0.1 per cent p-nitrosodimethylaniline stock solution. Eastman Kodak Co. Cat. No. 188. The nitroso-compound is dissolved by gradual addition to distilled water which is just below the boiling point. The solution is then cooled and will keep for several weeks under refrigeration. The diamine reagent is prepared immediately before use by allowing a suitable amount of the reagent to come to room temperature, then shaking it in the presence of a large excess of zinc dust until decoloration is complete. The reduction is hastened by the addition of one drop of 10 per cent $CuSO_4$ solution for every 10 ml. of reagent. The excess of Zn is filtered off, and the filtrate then usually exhibits a pale pink tinge, which is not detrimental, and must be used immediately.
6. $NaHCO_3$—a 5 per cent aqueous solution for a pH of 8.3 to 8.5.
7. A hypochlorite solution containing 0.05 per cent of available chlorine. This solution is made by diluting 10 ml. of "Clorox" solution to 1,000 ml. This solution is stable if kept cool and away from sunlight.
8. Iso-amyl alcohol or carbon tetrachloride, reagent grade.
9. Standard phenol solution—a 0.1 per cent aqueous phenol solution made from reagent grade phenol.

Summary

The p-nitrosodimethylaniline method has been investigated and has given consistent results on several trade wastes. The optimum amount of reagents and pH have been determined, as well as other operating variables. The method has been made applicable for use on a spectrophotometer or filter photometer. A technique was devised to decrease the effect of interfering substances. Iso-amyl alcohol extraction greatly increases the sensitivity in the lower concentration ranges.

Acknowledgment

The authors wish to express their appreciation to the National Institutes of Health, U. S. Public Health Service, and the Federation of Sewage and Industrial Wastes Associations for funds to carry out the work described herein.

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APPRAISAL OF A CHEMICAL WASTE PROBLEM BY FISH TOXICITY TESTS*

By Leslie A. Gillette, Dwight L. Miller, and H. E. Redman

Sharples Chemicals, Inc., Wyandotte, Mich.

Chemical plants potentially can discharge wastes containing any of their manufactured products, intermediates, or raw materials. The relative toxicity of these chemicals to fish and animal life is a function of such variables as concentration, temperature, alkalinity, etc. A waste disposal or treatment program must include an evaluation of chemical toxicity limits separately or in combination to determine (a) toxic compounds, (b) dilution requirements, and (c) products on which to concentrate for disposal investigations.

The following is a discussion of such a program:

Sharples Chemicals manufactures at Wyandotte, Mich., approximately 100 different chemicals. The major chemicals are alkylamines, alkylphenols, rubber chemicals, amyl alcohols, amyl acetate, mercaptans, hydrochloric acid, and organic detergents.

The plant is located approximately 0.5 mi. from the Trenton Channel of the Detroit River. The plant liquid wastes reach the river through a slow-moving creek and swamp area, which flows through public and private property. In the past the creek drained a large section of the area south of Wyandotte, but industrial and residential development of the area with corresponding sewer installations have changed this so the creek no longer serves its original function and now drains a very limited area.

Cooling waters are pumped from the Detroit River approximately 0.5 mi. above the stream discharge. This water contains quantities of chemicals from the industrial area along the Detroit River above the intake. Normal chemical losses and occasional spills mix with these cooling waters, pass through impounding ponds and oil separators, and are discharged to outfall sewers. The volume of water varies from 5 to 6 m.g.d., which is diluted approximately 5,000 times when completely mixed with waters in the Trenton Channel of the Detroit River.

Originally it was planned to install an elaborate chemical sewer and segregation system, and central treating system including trickling filters, clarifiers, incinerators, and accessory equipment for treatment of the wastes prior to discharge. However, concentrations of specific chemicals in the discharge water vary several hundred per cent. Chemical analyses by known analytical procedures did not give results which could be directly related to waste toxicity. Since Sharples is the only producer of many of the chemicals, analytical and toxicity information was unavailable or had to be developed.

Development Program

Installation and operating costs threatened to become prohibitive. An alternate procedure became a must. With the consultation and assistance of the Michigan Water Resources Commission it was concluded that the most logical development program was to:

1. Carry out an extensive investigation to determine the toxicity of the raw materials and finished products to fish and animal life.

* Presented at 1952 Annual Meeting, Michigan Sewage and Industrial Wastes Assn.; Traverse City, Mich.; May 19–21, 1952.

2. Eliminate or reduce at the source all possible chemical losses.

3. Segregate the chemical wastes where possible.

4. Treat the more toxic materials and hold below the toxic level.

5. Install holding ponds, oil separators, and similar equipment to make the discharged wastes uniform and of minimum toxicity.

One of the first indications of a toxic contaminant in an effluent water is the presence of distressed or dead fish in the receiving stream. To identify a contaminating material in the plant effluent water is a difficult problem, especially when a considerable number of similar compounds may be involved. An alternative to identifying a contaminant causing a toxic condition in the effluent water is the determination of the toxic level of the possible contaminants. On the basis that more valuable information would be obtained by determining the toxic level, the program was initiated to determine the relative toxic level, to freshwater fish, of the chemicals used and manufactured by Sharples.

Test Fish and Control Water

The test fish used in this program was the creek chub (*Semotitus a. atromaculatus*). The chub has an average sensitivity to toxic materials and other adverse conditions, being more hardy than the Great Lakes shiner and less hardy than the goldfish.

The fish were obtained from a commercial bait dealer and were quite uniform in size, being 3 to 4 in. in length. A week's supply of fish was obtained on Monday and kept in a stock tank through Friday. The fish in the stock tank were fed commercial goldfish food every other day.

The water used for control water and for dilution of the materials tested was the stock tank water, which was obtained fresh from the East Channel of the Detroit River at the east bank of Grosse Ile. This water sustains the normal amount of fish life found in the Great Lakes area and was considered to be of average quality, with the following typical analysis:

Constituent	P.p.m.
Silica (SiO_2)	2.9
Iron (Fe)*	0.02
Calcium (Ca)	27.0
Magnesium (Mg)	7.3
Sodium (Na)	6.7
Potassium (K)	2.2
Manganese (Mn)	0.0
Carbonate (CO_3)	6.0
Bicarbonate (HCO_3)	88.0
Sulfate (SO_4)	14.0
Chloride (Cl)	9.0
Fluoride (F)	0.10
Nitrate (NO_3)	0.60
Dissolved solids	120.0
Total hardness, as $CaCO_3$	98.0
Color	3.0
pH	8.3
Specific conductance at 25° C. (micromhos)	218.

* In solution when analyzed.

The stock tank was aerated continuously and the temperature maintained at 18° to 21° C. by means of a glass cooling coil connected to the tap water and immersed in the stock tank.

The plant compressed air contained a small amount of entrained oil, which is harmful to the fish, and it was necessary to filter the air through cotton before using it to aerate the stock tank and test jars.

Test Method

The test method employed to determine the relative toxic level, throughout this program, was to place 3,000 ml. of test solution in a 1-gal. glass jar equipped with a glass aerating tube and a cover with an air release. Four fish were retained in each test solution for 24 hr. At frequent intervals the condition of the fish was observed and any dead fish were removed to avoid contamination. The temperature of the test solutions was maintained between 15° and 21° C. by placing the test jars in a shallow trough of running tap water. A constant stream of air was forced through the water in the test jars to maintain the dissolved oxygen content.

For each chemical, a series of tests was conducted over a range of concentrations, the extent of the range depending on the nature of the material. A control jar, using stock water, was run each day that toxicity tests were run. The concentration of the chemical tested was expressed in parts per million and the toxicity of the chemical is expressed as the "critical range," defined as the range in concentration in parts per million below which the four fish all lived for 24 hr. and above which they all died.

Materials

The chemicals used for the toxicity tests were all products manufactured by Sharples Chemicals, Inc., or purchased for use in manufacturing operations. The purity of the Sharples products was that specified for commercial sale and in most cases the materials were reasonably pure. All of the chemicals were tested as obtained without any further purification.

The test solutions of the chemicals were prepared by dissolving a known weight in a given volume of water and computing the parts per million for this solution. Lower concentrations were prepared by dilution with stock water.

Experimental Results

The toxicity determinations in this study are intended to be used for the purpose of evaluating the relative toxicity of the chemicals tested, using the creek chub as the test fish. The data presented in this report could possibly be correlated with other existing data, but should not be construed as the true toxic level for this fish living in its natural habitat.

Table I lists the chemicals tested and the critical range for each in order of decreasing toxicity. These data show that all the amines are highly toxic and that six other materials—namely, sodium hydrosulfide, ammonium hydroxide, phenol, sodium hydroxide,

TABLE I.—Critical Range of Toxicity to Fish for Various Chemicals

Chemical Compound	Critical Range (p.p.m.)
1. Sodium hydrosulfide	4 to 10
2. Ammonium hydroxide (as NH_3)	5 to 15
3. Diamylamine	5 to 20
4. Bis benzyl ethylene diamine diacetate	5 to 20
5. Phenol	10 to 20
6. Monomethylamine	10 to 30
7. Di-sec-butylamine	15 to 40
8. Sodium hydroxide	20 to 40
9. Tri-n-butylamine	20 to 40
10. Di-isobutylamine	20 to 40
11. Mono-sec-butylamine	20 to 60
12. Mono-isobutylamine	20 to 60
13. Di-n-propylamine	20 to 60
14. Di-n-butylamine	20 to 60
15. Nonic 218[1]	20 to 60
16. Dimethylamine	30 to 50
17. Monoethylamine	30 to 50
18. Ethylene diamine	30 to 60
19. Monoamylamine	30 to 50
20. 1, 3 dibutylthiourea	30 to 100
21. Mono-n-butylamine	30 to 70
22. Tri-n-propylamine	30 to 70
23. Di-isopropylamine	40 to 60
24. Mono-n-propylamine	40 to 60
25. Monoethylethanolamine	40 to 70
26. Monoisopropylamine	40 to 80
27. Triethylamine	50 to 80
28. Amyl acetate	50 to 120
29. Hydrochloric acid	60 to 80
30. Diethylamine	70 to 100
31. Diethylethanolamine	80 to 120
32. Acetic acid	100 to 200
33. 1, 3 diethylthiourea	100 to 300
34. Ethyldiethanolamine	160 to 200
35. n-propyl alcohol	200 to 500
36. n-amyl alcohol	350 to 500
37. Mixed primary isoamyl alcohols	400 to 600
38. Sodium nitrite	400 to 2,000
39. Diethylnitrosoamine	900 to 1,100
40. Isopropyl alcohol	900 to 1,100
41. n-butyl alcohol	1,000 to 1,400
42. Buramine[1]	1,000 to 1,500
43. Tert-amyl alcohol	1,300 to 2,000
44. Endothal[1]	1,600 to 3,200
45. Tert-butyl alcohol	3,000 to 6,000
46. Diethylaminohydrochloride	4,000 to 6,000
47. Ethylene thiourea	6,000 to 8,000
48. Ethyl alcohol	7,000 to 9,000
49. 1,3 dimethylurea	7,000 to 15,000
50. Methyl alcohol	8,000 to 17,000
51. Urea	16,000 to 30,000

[1] Trade name.

TABLE II.—Toxicity Data on Sodium Hydroxide [1]

Time (hr.)	Test Jar Number and Concentration					
	No. 1 Control	No. 2 10 p.p.m.	No. 3 20 p.p.m.	No. 4 30 p.p.m.	No. 5 40 p.p.m.	No. 6 50 p.p.m.
0	4N	4N	4N	4N	4N	4N
1	4N	4N	4N	1D, 3N	3D, 1N	4D
1.5	4N	4N	4N	2D, 2N	4D	—
7.5	4N	4N	4N	2D, 2N	—	1 hr.
22.5	4N	4N	4N	2D, 2N	1.5 hr.	
24	4N	4N	4N	2D, 2N		
	24 hr.	24 hr.	24 hr.	24 hr.		

[1] All the fish were alive after 24 hr. at 20 p.p.m. and all dead at 40 p.p.m. so the critical range is 20 to 40 p.p.m.

TABLE III.—Toxicity Data on Dimethylamine

Time (hr.)	Test Jar Number and Concentration					
	No. 1 Control	No. 2 10 p.p.m.	No. 3 30 p.p.m.	No. 4 50 p.p.m.	No. 5 70 p.p.m.	No. 6 90 p.p.m.
0	4N	4N	4N	4N	4N	4N
0.5	4N	4N	4N	4N	4N	4D
0.75	4N	4N	4N	4N	2D, 2N	—
1.0	4N	4N	4N	4N	4D	0.5 hr.
3.0	4N	4N	4N	4D	—	
19.0	4N	4N	4N	—	1 hr.	
24.0	4N	4N	4N	3 hr.		
	24 hr.	24 hr.	24 hr.			

TABLE IV.—Toxicity Data on Dibutylthiourea

Time (hr.)	Test Jar Number and Concentration					
	No. 1 Control	No. 2 10 p.p.m.	No. 3 30 p.p.m.	No. 4 50 p.p.m.	No. 5 100 p.p.m.	No. 6 200 p.p.m.
0	4N	4N	4N	4N	4N	4N
0.5	4N	4N	4N	4N	4N	4D
1.5	4N	4N	4N	4N	4D	—
7.0	4N	4N	4N	1D, 3N	—	0.5 hr.
24.0	4N	4N	4N	3D, 1N	1.5 hr.	
	24 hr.	24 hr.	24 hr.	24 hr.		

Nonic 218, and 1,3 dibutylthiourea are equally and in some cases more toxic than the amines.

Throughout this program it has been noticed that the fish usually succumbed within 3 to 4 hr. or survived for 24 hr. This was particularly true with the amines. The reason for this behavior could be that the stream of air through the test water volatilized a portion of the toxic material.

Tables II, III, IV, V, VI, and VII, representing different types of chemicals, illustrate how the critical range, presented in Table I, was determined. In each case four fish were used in each jar; N = normal fish, D = dead fish. In each case the highest concentration in which all fish lived for 24 hr. represents the lower limit of the toxic range, the upper limit of the toxic range being

TABLE V.—Toxicity Data on Mixed Amyl Alcohols

Time (hr.)	Test Jar Number and Concentration					
	No. 1 Control	No. 2 300 p.p.m.	No. 3 400 p.p.m.	No. 4 500 p.p.m.	No. 5 600 p.p.m.	No. 6 700 p.p.m.
0	4N	4N	4N	4N	4N	4N
2.25	4N	4N	4N		4D	4D
5.75	4N	4N	4N	2D, 2N		
24.0	4N	4N	4N	2D, 2N	2.25 hr.	2.25 hr.
	24 hr.	24 hr.	24 hr.	24 hr.		

TABLE VI.—Toxicity Data on Phenol

Time (hr.)	Test Jar Number and Concentration					
	No. 1 Control	No. 2 5 p.p.m.	No. 3 10 p.p.m.	No. 4 15 p.p.m.	No. 5 20 p.p.m.	No. 6 25 p.p.m.
0	4N	4N	4N	4N	4N	4N
0.5	4N	4N	4N	4N	4N	4D
0.75	4N	4N	4N	4N	4D	
21.0	4N	4N	4N	1D, 3N		0.5 hr.
24.0	4N	4N	4N	1D, 3N	0.75 hr.	
	24 hr.	24 hr.	24 hr.	24 hr.		

TABLE VII.—Toxicity Data on Hydrochloric Acid

Time (hr.)	Test Jar Number and Concentration					
	No. 1 Control	No. 2 20 p.p.m.	No. 3 40 p.p.m.	No. 4 60 p.p.m.	No. 5 80 p.p.m.	No. 6 100 p.p.m.
0	4N	4N	4N	4N	4N	4N
1.0	4N	4N	4N	4N	4N	4D
21.0	4N	4N	4N	4N	4D	1 hr.
24.0	4N	4N	4N	4N		1 hr.
	24 hr.	24 hr.	24 hr.	24 hr.	21 hr.	

the lowest concentration in which all fish were killed in 24 hr.

Summary and Conclusions

The most dangerous contaminants of the plant effluent water are the simple alkyl amines, sodium hydrosulfide, ammonium hydroxide, phenol, sodium hydroxide, Nonic 218, and 1,3 dibutylthiourea. By comparing the toxic level of diethylamine and diethylamine hydrochloride it is apparent that by adjusting the pH of the effluent water to 7.0 to 7.5, the number of highly toxic materials would be reduced to four; namely, phenol, sodium hydrosulfide, Nonic 218, and 1,3 dibutylthiourea.

Acknowledgments

The writers wish to acknowledge the suggestions given by Professor A. S. Hazard, Director, Institute of Fisheries Research, University of Michigan. Also acknowledged is the help given by L. F. Oeming, Chief Engineer, Michigan Water Resources Commission. The Detroit River raw water analysis was obtained from the Wyandotte, Mich., Department of Municipal Service.

WHITE WATER TREATMENT *

III. Factors Affecting Digestion Efficiency

By Willem Rudolfs and Herman R. Amberg

Rutgers University, New Brunswick, N. J.

The problem of alleviating the effect of various concentrations of soluble sulfide upon the methane fermentation (1) can be approached through (a) sulfate removal from the waste prior to feeding, (b) precipitation of the sulfide as it is formed, (c) two-stage digestion, and (d) removal of sulfide by blowing an inert gas through the digestion mixture.

Sulfate removal from the feed liquor or waste is not feasible, because the majority of cations which could be used to precipitate the sulfate are toxic to the methane fermentation. The other three methods are feasible and were investigated.

Miller (3), working with *Desulfovibrio desulfuricans*, found that when hydrogen sulfide was precipitated as an insoluble sulfide, the total amount of sulfide formed was larger than in the controls, indicating that the presence of high concentrations of hydrogen sulfide in the medium tend to retard further growth of bacteria. Growth took place most readily in the presence of cadmium, iron, antimony, bismuth, and lead compounds tested. The use of iron to precipitate the sulfides as they are formed is feasible because insoluble ferrous sulfide does not affect methane fermentation.

Since sulfides have a differential effect upon the two stages of digestion (acid production and gasification), it can be postulated that separation of the two stages would be beneficial. The first stage could consist of acid production and sulfate reduction. The sulfide produced in this first stage could then be removed by chemical or with an inert gas (flue gas). Following the preliminary or preparation stage, methane fermentation would take place. The feasibility of this scheme depends upon the efficient reduction of sulfates in the first stage, thus eliminating or keeping the sulfide concentration in the second stage to a minimum.

Removal of sulfides during the digestion process by aeration with an inert gas should be most advantageous, as the sulfide concentration can be kept at a minimum and the success of the system does not depend upon efficient and complete reduction of the sulfates.

Materials and Methods

Samples of white water concentrated from approximately 350 to 2,000 p.p.m. B.O.D. were mixed with ripe sewage sludge, and diammonium acid phosphate was added to insure a B.O.D. to nitrogen ratio of 20.

For experiments using nitrogen and carbon dioxide to remove H_2S, a special digestion apparatus was used (Figure 1). Nitrogen and carbon dioxide gas were fed from pressure cylinders at a controlled rate by a solenoid valve activated by the timing mechanism. The gas outlet from the digester was connected to a sulfide scrubber containing a 2 per cent zinc acetate solution.

Precipitation of Sulfides

The use of iron to precipitate the sulfides as they are formed was investigated with 0, 50, and 100 p.p.m. Fe^{+++}

* Paper of the Journal Series, New Jersey Agricultural Experiment Station.

in the form of $FeCl_3$. Ammonium carbonate was used as a source of nitrogen and for the neutralization of the daily feed addition. A preliminary acclimatization period of 3 weeks was used with gradually increasing loadings.

Average results for the highest daily loading were as follows:

Fe^{+++} Added (p.p.m.)	Gas (c.c./g. vol. sol. added)	B.O.D.		
		Infl. (p.p.m.)	Eff. (p.p.m.)	Red. (%)
0	199	1,940	890	54.1
50	209	1,940	766	60.5
100	193	1,940	756	61.0

Additions of 50 and 100 p.p.m. Fe^{+++} improved the digestion process slightly, although the addition of 100 p.p.m. Fe^{+++} showed no improvement over the 50-p.p.m. addition.

The soluble sulfide contents of the digesters at various time intervals (Table I) show a gradual increase with time in all digesters, the sulfide concentration being practically equal in all of the digesters at the completion of gasification.

Very little improvement was accomplished by the addition of the quantities of $FeCl_3$ employed. Ordinarily, without the iron additions, more hydrogen sulfide would escape as gas, and in the presence of iron less H_2S escaped because a portion does react with the iron.

TABLE I.—Soluble Sulfide Concentration in Digestion Mixture (p.p.m. $S^=$)

Time (days)	Fe^{+++} Addition (p.p.m.)		
	0	50	100
1	56	48	0
8	80	60	44
12	155	137	71
13	149	107	82
14	144	125	93
15	150	110	101
19	159	145	125
21	155	150	137

The control digester after 12 days of digestion reached an equilibrium concentration of soluble sulfide which was not exceeded during the course of digestion. This phenomenon has been noted in previous experiments; that is, upon reaching a sulfide concentration of approximately 150 to 170 p.p.m., the sulfide concentration leveled off and remained fairly constant. At this sulfide concentration only partial sulfate reduction had been ac-

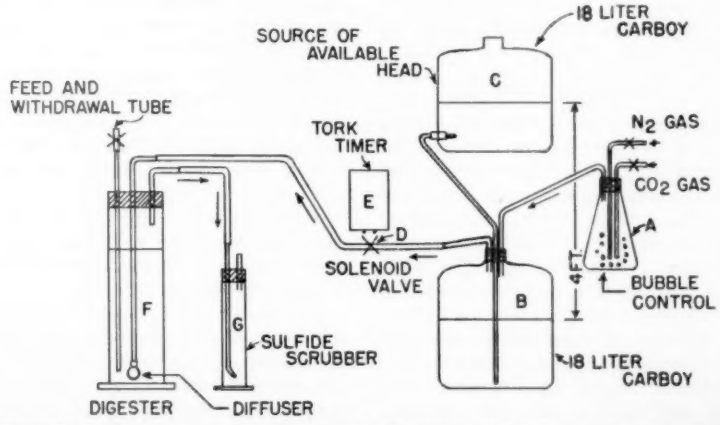

FIGURE 1.—Digestion apparatus for removal of sulfides with nitrogen and carbon dioxide.

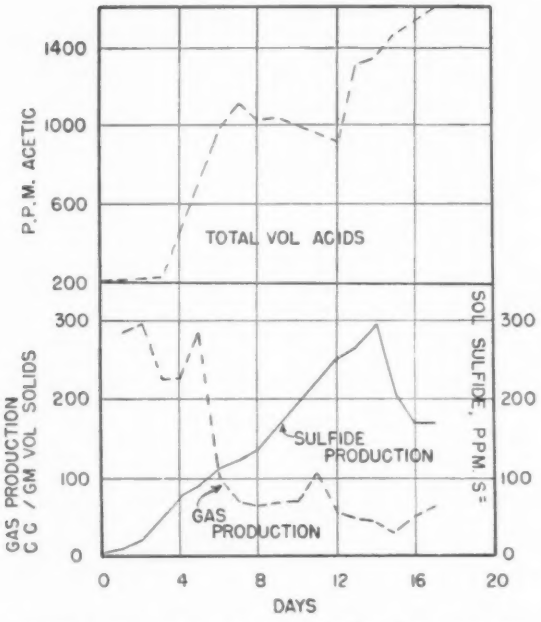

FIGURE 2.—Volatile acids, sulfide, and gas production during first stage of digestion.

complished. Despite the lag in sulfide concentrations with increasing quantities of iron, the sulfide concentrations reached eventually about the same concentration as without iron addition, indicating that for sulfide control impractical iron dosages would be required.

Two-Stage Digestion

To study the feasibility of separation of the two stages of digestion, concentrated white water was added to a primary digester at a loading of 0.06 lb. of B.O.D. per cubic foot of digester capacity per day for the production of volatile acids. The reaction was controlled near neutrality (the optimum for the sulfate reducers) by addition of ammonium carbonate and diammonium acid phosphate.

After 17 days of digestion, with daily additions, a peak in acid production was reached (Figure 2) which leveled off at approximately 1,600 p.p.m. (calculated as acetic acid). Sulfide concentration increased rapidly and gas production dropped suddenly in the first stage after a few days of digestion. The average sulfate reduction was only 40 per cent with a maximum reduction of 58 per cent, leaving a residual sulfate content of approximately 1,000 p.p.m. in the effluent (Figure 3).

The effluent from the first-stage digestion was divided into two equal portions; one was aerated for 20 min. with CO_2 to remove the soluble sulfide prior to the addition to the second stage, and the other was added directly to a second-stage digester.

The second-stage digester receiving sulfide-free waste produced an average of 63 per cent more gas than the control, which received aerated waste, but in both cases the gas production gradually decreased with daily additions to

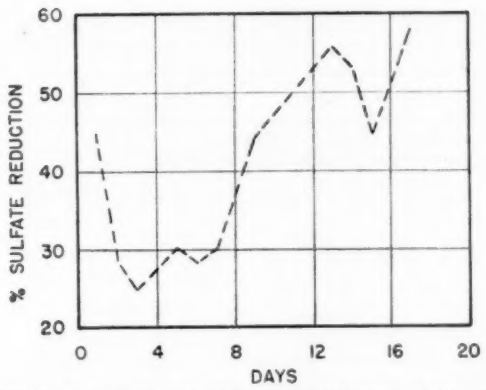

FIGURE 3.—Sulfate reduction during first stage of digestion.

less than one-fourth of the gas produced during the first few days.

The sulfide concentration in the digester receiving sulfide-free waste increased from 23 p.p.m. $S^=$ at the beginning to 160 p.p.m. $S^=$ at the end of 12 days of digestion, whereas the sulfide concentration in the control reached 165 p.p.m. after 2 days and varied between 18 and 190 p.p.m. for the remainder of the experiment. The decrease in gas production coincided with the increase in sulfide concentration.

From the results obtained it appears that two-stage digestion is not feasible unless high sulfate reductions are obtained during the first stage. Removal of sulfides formed in the first stage is feasible, but if sufficient sulfates remain the sulfide concentration soon increases to the toxic level in the second stage.

Removal of H_2S During Digestion

To remove the soluble sulfide as formed, a mixture of nitrogen and carbon dioxide ($N_2/CO_2 = 5$, by volume) was bubbled through the digestion mixture. The gas was scrubbed with zinc acetate, the sulfides were determined daily, and the soluble sulfides in the digestion liquor were determined every other day. Ripe sewage sludge was used as seed and the white water B.O.D. loading was increased from 0.02 to 0.045 lb. per cu. ft. per day.

The results after 24 days of operation show that with a B.O.D. loading of approximately 0.03 lb. per cu. ft. per day of digester capacity, an average of 70 per cent of the sulfur was recovered in the scrubber; with a B.O.D. load of 0.045 lb. per cu. ft. per day the sulfur recovered in the scrubber ranged from 50 to 60 per cent. The soluble sulfide concentration in the digestion mixture was below 10 p.p.m. at all times.

At the lower B.O.D. loading an average of 78 per cent of the B.O.D. was removed, whereas at the increased loading approximately 70 per cent of the B.O.D. was reduced. However, after a week of digestion at the higher loading the efficiency dropped to 50 per cent.

In previous work it was found that the optimum sulfate reduction was 60 per cent and that this optimum was seldom approached. Aeration with N_2 and CO_2 resulted in appreciably increased sulfate reduction.

The aeration intervals used were sufficient to maintain the soluble sulfide concentration below 10 p.p.m. Even with this low sulfide concentration it was impossible to exceed the

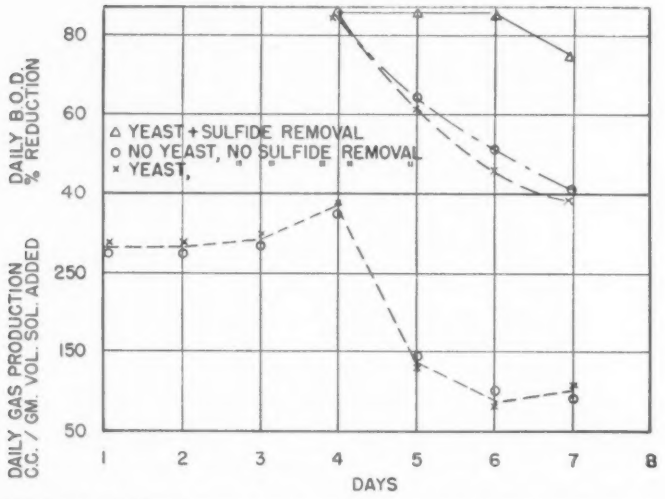

FIGURE 4.—Effect of yeast extract on B.O.D. reduction and gas production.

B.O.D. loading of 0.045 lb. per cu. ft. per day. This low efficiency may be attributed to one or a combination of the following factors: (a) complexity of the organic material, (b) deficiency of growth stimulating substances, and (c) presence of toxic metabolic end products other than sulfides.

Volatile acids reached a concentration of 1,200 p.p.m. (calculated as acetic) at the completion of the experiment. Since lower volatile acids were produced, which are readily available for the methane producers, the low efficiencies cannot be attributed to the complexity of the organic material.

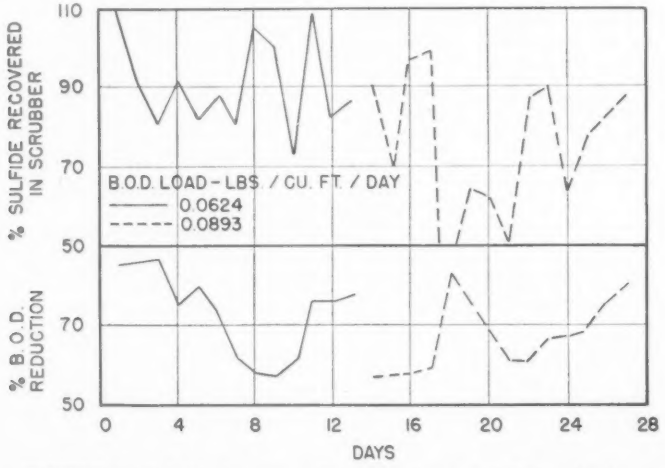

FIGURE 5.—Relation between sulfate reduction and B.O.D. reduction.

None of the studies indicated the production of toxic materials other than sulfides. It is possible, however, that during digestion of a carbohydrate waste such as white water a deficiency of growth-stimulating substances may develop and with the addition of an adjuvant, such as yeast extract, the rate of methane production can be materially increased.

Effect of Sulfide Removal and Addition of Yeast Extract

Heukelekian and Heineman (2) found that the addition of a growth-stimulating substance, such as yeast extract, to a culture of methane-producing organisms was of practical value in reducing the time necessary for incubation. It seemed possible that by a combination of sulfide removal and addition of an adjuvant the efficiency of the digestion of white water could be improved. The sulfides were removed as described previously, and yeast extract was added to the daily additions of white water.

Three portions of ripe sewage sludge added to 3 digesters resulted in the following conditions with daily additions of concentrated white water:

Digester Number	Sulfide Removal	Yeast Extract Added (p.p.m.)
1	No	0
2	No	600
3	Yes	600

The results of the first 7 days of digestion (Figure 4) show that the two digesters not aerated with nitrogen and carbon dioxide produced approximately the same gas volume per unit volatile matter added and that after 4 days of digestion, gas production dropped sharply. The digester aerated with carbon dioxide and nitrogen and with yeast extract added was much more efficient in the reduction of B.O.D. than the other two digesters. Figure 5 shows the daily B.O.D. reductions for two loadings used. For the low loading a drop in efficiency occurred after 6 days of digestion and recovery occurred after approximately 10 days of digestion. The drop in efficiency can be attributed to the decomposition of the yeast extract solution. Although the yeast extract was stored at 5° C., after 6 days a heavy growth occurred in the flask and the color of the solution changed from dark to light brown. When freshly prepared yeast extract solution was added the efficiency again increased. The efficiency again dropped when the loading was increased, and it improved as the experiment progressed.

The pH of the digester was controlled by changing the ratio of carbon dioxide to nitrogen. When the pH of the digester dropped below 7.0, the CO_2 rate was decreased and an alkaline reaction (7.6) could be maintained. At the higher B.O.D. loading the volume ratio of CO_2 to N_2 was approximately 0.1.

At a B.O.D. loading of 0.06 lb. per cu. ft. per day of digester capacity, the sulfide sulfur recovered in the scrubber ranged from 80 to 110 per cent of the sulfate sulfur added. When the loading was increased to 0.09 lb. per cu. ft. per day, daily variations were greater, with the sulfide recovery ranging from 50 to 100 per cent. Sulfate analyses on the effluent showed only traces of sulfate sulfur.

Discussion

The addition of $FeCl_3$ to digestion mixtures to precipitate the sulfides as they are formed was found to be ineffective with Fe^{+++} concentration up to 100 p.p.m. The soluble sulfide increased to the toxic concentration as the digestion process continued. Because soluble sulfides have a differential effect upon the two phases of digestion (acid production and methane fermentation) two-stage digestion suggested itself, the effluent of the first digester being aerated with CO_2 to remove the sulfides prior to the addition to the secondary digester for methane fermentation. However, only

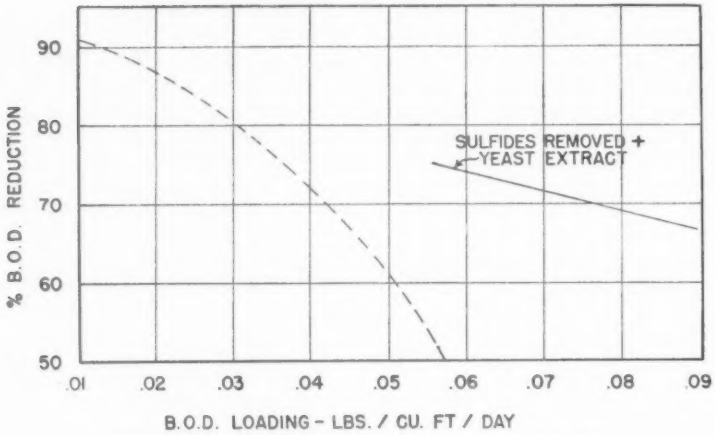

FIGURE 6.—Effect of B.O.D. loading in B.O.D reduction.

approximately 50 per cent of the sulfate was reduced in the first stage, leaving a residual sulfate concentration of 1,000 p.p.m. The sulfide concentration in the secondary digester soon reached the toxic concentration and methane fermentation ceased. Aeration of the digestion mixture with a mixture of CO_2 and N_2 gas at hourly intervals to remove the sulfides as they are formed resulted in higher sulfate reductions, but no significant increase in gasification.

By using a combination of sulfide removal and the addition of an adjuvant (yeast extract) it was possible to increase the digestion efficiencies. Yeast extract by itself has no beneficial effect upon the digestion, as the soluble sulfide concentration in the digester receiving yeast extract was higher than that in the control.

A comparison of the efficiencies obtained in daily addition experiments and efficiencies obtained by a combination of sulfide removal and yeast extract addition (Figure 6) shows that loadings can be doubled by the addition of an adjuvant and sulfide removal, without impairing the degree of purification.

Although the B.O.D. loadings were increased considerably by the addition of yeast extract and by sulfide removal, the digestion process is still unwieldly from a practical standpoint. Moreover, at practical loadings only 70 per cent of the applied B.O.D. could be reduced.

Conclusions

From the experimental data obtained the following conclusions have been drawn:

1. Two-stage digestion and aeration of the first-stage effluent to remove the sulfides prior to the loading of the secondary digester is not feasible, because sulfate reduction is not complete in the primary unit and a subsequent build-up of sulfides in the secondary unit results in failure of the fermentation.

2. The addition of yeast extract to the digestion mixture enhances sulfate reduction but has no noticeable effect upon the methane fermentation unless the sulfides are removed as they are formed.

3. A combination of yeast extract additions and aeration of the digestion mixture with mixtures of CO_2 and N_2

to remove the sulfides as they are formed allows increased B.O.D. loadings to 0.09 lb. per cu. ft. per day, with approximately 68 per cent B.O.D. reduction in a detention period of 3 days.

Summary

Sulfides in relatively low concentration have a retarding effect upon gasification. Digestion studies conducted with concentrated white water to eliminate the sulfides formed showed that the addition of ferric chloride in concentrations up to 100 p.p.m., as Fe^{+++}, was ineffective in improving digestion. Two-stage digestion, consisting of sulfate reduction and acid production in the first stage followed by a secondary unit for methane fermentation, was ineffective because of low sulfide reductions in the primary unit and subsequent sulfide accumulation in the secondary unit. A combination of sulfide removal by aeration with CO_2 and N_2 gas and yeast extract additions resulted in a two-fold increase in the loading. At optimum digestion conditions, approximately 68 per cent of the B.O.D. can be reduced at an applied B.O.D. load of 0.09 lb. per cu. ft. of capacity per day.

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OHIO VALLEY SEWAGE TREATMENT PROGRESS

Significant changes in the municipal sewage treatment picture reported to the Ohio River Valley Water Sanitation Commission at its October 1, 1952, meeting were as follows:

New Plant Status	*Number*	*Pop. Served*
In operation	22	61,000
Under construction	25	555,300
Final plans approved	47	326,700
Total	94	943,000

Two public hearings have already been held by the Commission on sewage treatment requirements in a 190-mi. stretch of the Ohio River, with others to follow shortly. Meantime, the Commission is issuing notices for compliance to 19 municipalities and industries in Ohio, 25 in Kentucky, and 6 in West Virginia, which are now discharging sewage in the sections where public hearings have been conducted.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

WHAT'S RIGHT WITH MY PLANT *

BY EDWIN A. LOCKE

Operator, Sewage Treatment Plant, Hartford, Conn.

The Metropolitan District sewage treatment plant in Hartford, Conn., is located at the southeast edge of the city, inside the dike constructed along the Connecticut River. The plant was designed to operate only during non-freezing weather and when the Connecticut River stage is below the elevation of the effluent weirs. The actual shutdown period, however, has been only during the spring freshet season and is usually about two months. The plant buildings are constructed of brick with cast stone trim, and are well spaced on a level plot of land surrounded by a high chain-link fence. The enclosed area is landscaped and has well-kept lawns.

Plant Equipment

The sewage treatment equipment consists of a coarse rack or grizzly, mechanically-cleaned racks, grit chambers, sedimentation tanks, sludge digestion tanks, elutriation tanks, and vacuum filters. In 1951 the average sewage flow was about 31.0 m.g.d.

Sewage enters the plant through a gate house, in which are located electrically-operated main and by-pass sluice gates. Also in this building is a manually-cleaned coarse rack or grizzly, the center section of which can be opened to allow free flow in an emergency. Two waterproof lights with aluminum reflectors are located just above the top of the sewage conduit, so that the area at the grizzly is well lighted to aid operators in removing screenings.

Sluice gates in the rack house allow use of any combination of four grit chambers in order to maintain a fairly constant rate of flow through the grit channels. The fourth channel is a spare, as the present maximum flow is taken care of by three channels.

Each channel has a mechanically-cleaned rack, which can be operated continuously, on a timer, or by the loss of sewage head through the rack.

Screenings are deposited in large steel cans, which are picked up by an electric crane and transported to a hammer-mill type shredder for grinding and return to any one of the four channels, as selected.

Also installed in the rack house is an electrical control panel, which has push button stations with indicating lights, for the operation of all the main plant sluice gates; transfer switches for the ventilating fans, which may be run continuously or on timer; and a large flowmeter indicator showing the flow through the plant and calibrated to indicate the proper number of grit chambers to use for any given flow.

The grit screw conveyor discharge chutes in the rack house are located so that grit car bodies may be spotted at each conveyor to receive the grit.

* Presented as part of a symposium by the same title at 1952 Spring Meeting, New England Sewage and Industrial Wastes Association; Waterbury, Conn.; May 22, 1952.

The car bodies are easily handled by the traveling crane and the grit is hauled to the dump by electric locomotives.

Any organic solids that settle with the grit are washed out by operating the flight collectors in the bottom of the channel. A further washing is obtained in the hopper at the lower end of the screw conveyor by applying wash water through a 2-in. pipe terminating in the bottom of the hopper.

Sluice gates are provided at both ends of the grit chambers and a dewatering pump is installed in the gate house at the lower end of the grit chambers so that any or all of the channels may be emptied for inspection and maintenance.

Office Indicator Panel

A large panel on the office wall (Figure 1) has a schematic layout of the plant flow with colored indicating lights that show the position of the sluice gates, the number of grit chambers in use, the raw sludge collectors and sludge pumps in operation, which digesters are being filled or drawn, and which vacuum filters are operating. Also mounted on this panel are the plant flowmeter, which indicates, records, and totalizes the sewage flow; the Connecticut River level indicator; and indicating lights to show the street lighting circuits in operation.

Emergency Power

In case of loss of electrical power from the public utility, an emergency generator of 90-kw. capacity, driven by a gasoline engine, is ready at all times to supply power for operation of vital equipment. This unit is located on the main floor of the administration building near the main switchboard, so that the change-over can be made in a few minutes.

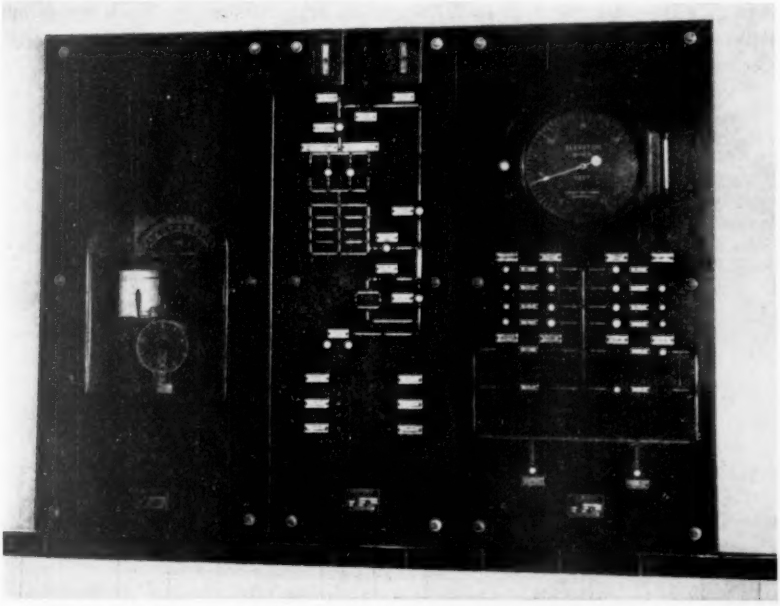

FIGURE 1.—Office panel, showing sewage flowmeter, indicating lights for plant units, and river level indicator.

Sedimentation Tanks

The wash-water pumps and supply tank are in the basement of the administration building. Duplicate pumps with large pressure tanks outside the building maintain an ample supply of wash water.

The influent channels for the sedimentation tanks are supplied with air to keep the sewage solids in suspension previous to entering the tanks. The compressor house contains two blowers, one being always in operation to keep a continuous supply of air to the diffuser tubes in the influent channels. To maintain a reasonably equal distribution of sludge in the eight sedimentation tanks, each is provided with four adjustable weirs to control the rate of flow into the tank.

The scum in the sedimentation tanks collects at a hanging barrier wall at the effluent end of the tank and is manually moved to scum pump hoppers at adjacent corners of each two tanks. A device called a "scum chaser" (Figure 2) has been developed by the plant operators to greatly assist this operation. It consists of a wash-water header running along the hanging barrier just below the scum level. At short intervals along this header, 90° angle nozzles of ¼-in. pipe are installed with the tip pointing in the direction of the scum hopper. When water is turned on, the scum is carried toward the receiving hopper and very little manual labor is required to complete the skimming operation.

The 8-inch raw sludge line from the raw sludge pump gallery to the digesters runs exposed for about 100 ft. along the top of the sedimentation tanks. Grease gradually deposits on the inside of this pipe, causing the pressure to rise to a point that is too high for safe operation of the pumps. A double wye has been installed in a convenient location in this exposed section of the line (Figure 3), so that by removing two blank covers on the wyes the pipe can be readily

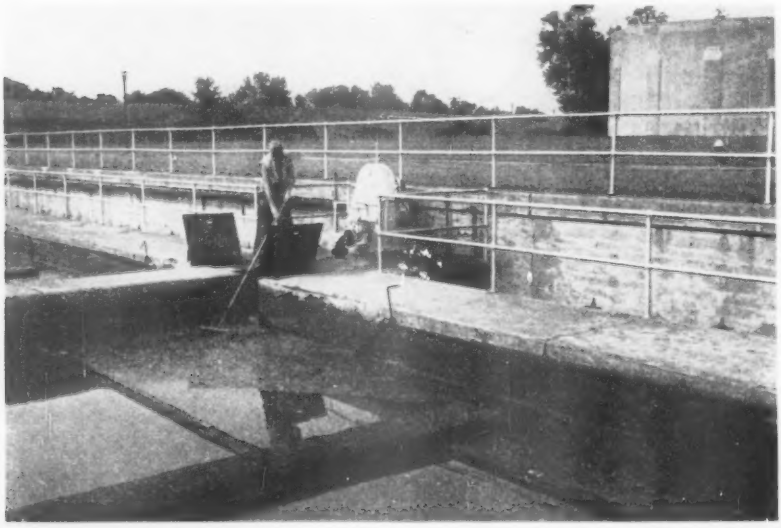

FIGURE 2.—Submerged "scum chaser" in operation on sedimentation tank.

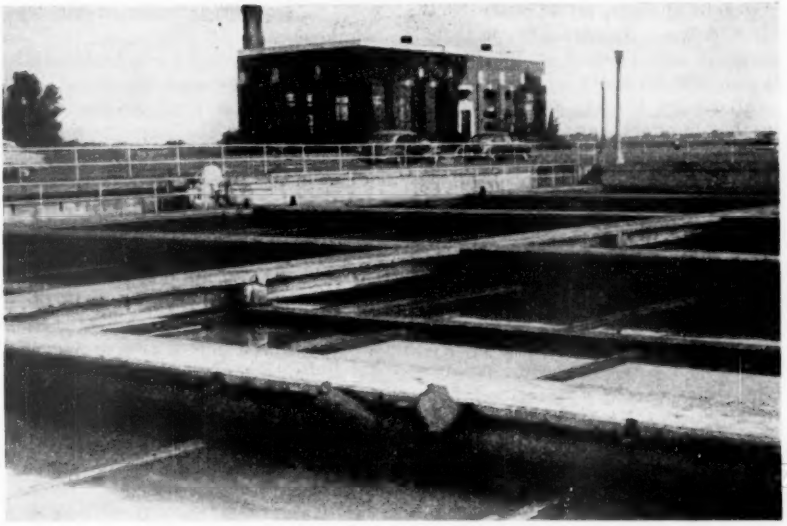

FIGURE 3.—Raw sludge line to digesters, exposed on sedimentation tank wall, is fitted with double wye to allow rodding for removal of grease accumulations.

cleaned in both directions with a sewer rodding machine.

The sedimentation gallery houses the eight duplex sludge pumps. The pumps are installed in batteries of two in a pit about 1 ft. lower than the floor, so that washing down after cleaning is a simple matter, and the main floor is kept clean and dry. A pressure gage on the raw sludge discharge header gives the pump operator an immediate indication of any undue rise in pressure and enables him to take necessary remedial measures. If the increase is due to heavy sludge, wash-water connections are provided on both suction and discharge sides of the pumps so that the sludge can be thinned with water.

Four sludge collector drives are inside the gallery, so that they are well protected from the weather and are easily accessible for maintenance.

Storehouse

The storehouse provides ample space for storage of the two electric locomotives, motor-generators for charging the batteries, gasoline pumps, portable blower, power lawn mowers, woodworking equipment, forge, spare parts, grease, oil, and paint. Much of the repair work is done in this building.

Digesters

There are four concrete digestion tanks with fixed covers. Between the four tanks is an operating gallery containing digester operating equipment.

Two 350-g.p.m. digested sludge pumps are located in the digester gallery (Figure 4). Headers are installed on both suction and discharge sides of the pumps so that sludge or supernatant can be pumped into and out of any tank at several levels. It has been found very convenient to mix either digested sludge or supernatant with the entering raw sludge to speed the start of digestion. These same pumps may be used for transferring the top or bottom contents of any di-

gester to another, or to pump to the filter house, if necessary, although normally the digested sludge flows to the elutriation tanks by gravity.

All sludge headers and connections to the digesters have 2-in. hose connections installed in blank flanges on the lines so that in case of a stoppage, wash-water pressure may be applied to clear the pipe.

A sampling sink is provided for each digester and samples of the contents may be drawn at 3-ft. elevation intervals from the bottom of the cone to the top of the tank. There are connections for removal of supernatant at four different elevations on each digester.

Each digester weir chamber is provided with a float-controlled water valve, which will keep the digester filled to the normal level in case sludge is drawn so fast that the equalizer connection from the other three digesters does not maintain the proper level of tank contents. This prevents an opening of the digester water seal, with consequent entrance of air into the dome.

The 2½-in. wrought-iron heating coils inside the digesters are divided into three sections so that the amount of heat applied to the contents may be varied between the top, middle, and bottom coils. The temperature of the water is automatically maintained at the heat exchangers. Flowmeters and indicating thermometers are located in the hot-water piping so that data for calculating the heat input to each digester may be readily obtained. Recording thermometers give a continuous indication of the temperature of the sludge, supernatant, or scum, as desired, by inserting the bulb in any one of several thermometer wells located in the digester wall at various elevations.

Individual gas lines from each digester terminate in the gas control house. In this building are drip pots, seal tanks, gas meters, pressure regulating equipment, and, on the roof, the waste gas burners. The drip pot and

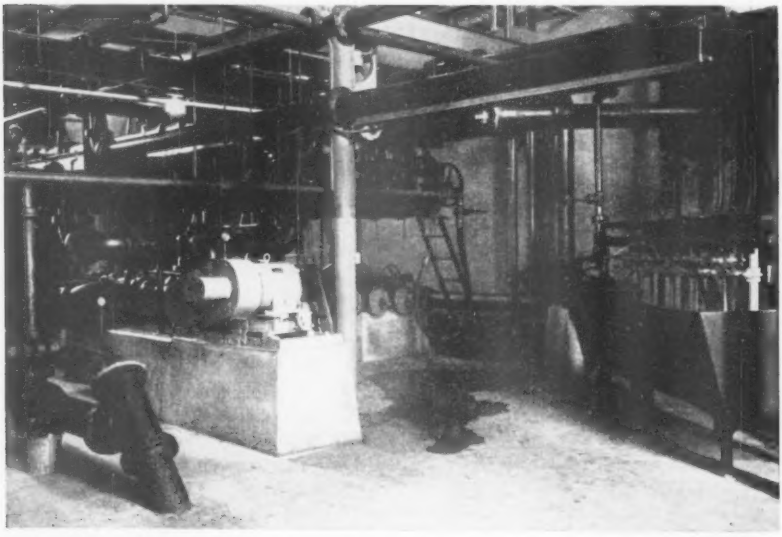

FIGURE 4.—Digester gallery, showing one sludge pump, suction and discharge headers, and one sampling sink.

gas meter on each gas line, as well as the seal tanks, may be automatically by-passed by a spring-loaded diaphragm valve in case of a stoppage in any of these units.

A failure in operation of the compressed air-operated pressure regulating valve will also cause diaphragm valves to open and allow gas to go to the waste burners, thus protecting the system from over-pressure.

Chart recorders are provided for recording the total gas produced, the gas used by the boilers, and the regulated gas pressure. Flame traps and water seal tanks prevent the propagation of gas combustion back through pipes to the digesters.

Vacuum Filters

The filter house contains two 8-ft. diameter by 14-ft. long vacuum filters and all auxiliary equipment, as well as a machine shop, heating boilers, heat exchangers, auxiliary wash-water system, well-water pumps for elutriating water, and a large chemical storeroom.

The filter vacuum pumps, filter blowers, elutriation pumps, well-water pumps, vacuum priming pumps, and sump pumps are all in duplicate, so there is always one in reserve in case of a breakdown.

Digested sludge is washed by counter-current elutriation, so that ferric chloride is the only conditioning agent needed before filtering.

Rate controllers are installed on the digested sludge, elutriated sludge, and well-water lines, so any predetermined flow is automatically maintained. Other automatic controls maintain a constant supply of elutriated sludge, feed ferric chloride according to the demand, and keep the filter vat filled to a predetermined level. Thus, once the filtering operation is started, it is only necessary to make adjustments of the controls when the character of the sludge or the filter cake changes.

Filter cake is discharged by belt conveyor into industrial railroad cars, which are hauled to a dumping area by an electric locomotive; therefore, no incineration is needed.

The boiler room is located in the basement of the filter house. The same idea of duplicate equipment is carried out in this room, with two boilers with combination gas or oil burners, two fuel oil pumps, and two hot-water circulating pumps.

Directly over the boiler room is the heat exchanger floor, where two steam-heated exchangers and the main digester heat control panel are located.

Constant temperature of the circulating hot water is maintained by automatically controlling the steam valves on the heat exchangers. The rate of flow of hot water to the digester heating coils is controlled by varying the speed of the pumps.

General

Because it is known that there will be an annual shutdown period of about two months, major replacements and maintenance are scheduled to be done at that time—a fortunate circumstance not obtaining in most plants.

In conclusion, the "rights" overbalance the "wrongs" in the plant, due in large measure to the excellence of the original design.

OHIO EXPERIENCE WITH SLUDGE HEAT EXCHANGERS *

I. Columbus Experience

By James H. Blodgett

Superintendent, Sewage Treatment Plant, Columbus, Ohio

During the latter part of 1951, a contract was completed that more than doubled the sludge digestion capacity of the Columbus, Ohio, sewage treatment plant. As a part of this contract, four heat exchangers of the water-jacketed tube type were installed for heating the sludge.

These heat exchangers are of comparatively simple design, as all of the heat required is furnished by circulating the power generating equipment jacket cooling water through the units in a closed system between the units and the engines. Water temperatures of 160° to 180° F. from this source are available for heating purposes on an average of 16 hr. per day, which has been found adequate for the plant needs.

The sludge circulates through 4-in. steel tubes swaged into end plates of a cylindrical tank in a manner similar to boiler construction. Each heat exchanger contains 16 tubes running horizontally through a cylindrical tank 10 ft. 6 in. long by 40 in. in diameter, giving 175 sq. ft. of radiation surface. Adjacent pairs of tubes are connected by cast-iron return bends, and special inlet and outlet pipe connections are provided. The connection between the tubes and the removable return bends is designed so that it is sealed with compression-type rubber gaskets, which form water-tight joints when the bends are bolted up tight onto the cylinder heads.

The water jacket is composed of a cylindrical shell divided into an upper and a lower section, by means of a diaphragm through the center, so that the hot water is required to pass from the bottom at one end through the heater and return through the top section and out the same end of the unit. The entire unit is surrounded with a steel frame on which is mounted an outer insulating cover composed of glass wool attached to sheet metal. This covering is removable for accessibility to the unit itself.

Automatic Heat Control

In normal operation, the sludge temperature on the incoming sludge line to the heat exchanger actuates an adjustable thermostatic control unit, which in turn operates a solenoid valve on the hot-water circulating line, thus controlling the flow of hot water to the heater. In this way, the sludge temperature may be maintained as desired, by setting the thermostat at any predetermined temperature that may be desired for the sludge in the digester.

Thermometers are provided on the inlet and outlet sludge lines, so that sludge temperatures may be observed, the efficiency of the heat exchanger calculated, and the need for cleaning the sludge lines determined from this information.

Provisions have also been made in the sludge piping so that the heat exchangers may be by-passed, in case it is desired to simply recirculate the sludge in the digester without passing it through the heat exchanger.

Hot-water lines entering and leaving the exchanger are equipped with thermometers so that the water tem-

* Symposium presented at 1952 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Toledo, Ohio; May 21–23, 1952.

perature differential can be determined. This information is necessary to compute the efficiency of the unit.

A connection also has been provided in the hot-water circulating line of each unit so that a water meter may be inserted for determining the volume of water passing through the exchanger during any unit of time. A single meter equipped with the necessary pipe connections is used for this purpose, being installed on each exchanger as required for tests.

The sludge, whether raw, mixed, or digested, by a system of interconnecting piping and centrifugal pumps, can be pumped through the heat exchangers.

The specifications called for each unit to be capable of exchanging 1,000,000 B.t.u. per hour when in normal operation.

Initial Operation Problems

It was planned that as soon as the units went into operation tests would be run to determine their efficiencies while in a new condition. This information was to be used as a basis of comparison for future tests, thereby indicating the need for cleaning or other adjustments to the units. When the units were placed in operation, however, so many "bugs" developed that no satisfactory tests were possible.

Gas Pockets

First, the location of the units is such that the liquid sludge must be pumped approximately 8 ft. vertically and then return the same distance before it can enter the digester. This places the exchangers at the high point in a loop, thus forming a natural gas pocket that restricts the flow of liquid.

Once the sludge is started circulating through these lines, and the flow is constantly maintained, it doesn't matter. But on intermittent operation, when the unit is shut off for a time, gas production from the sludge in the tubes of the exchangers rises to the top of the loop and forms a gas pocket, with consequent difficulties in re-establishing circulation of the sludge.

If, as happened a time or two, the inlet and outlet valves on the sludge lines were both closed during a shutdown of the units, the generated gas pressure became tremendous, resulting in blown gaskets and bad leakages in the tube connections at the end plates. Air relief valves had been provided to prevent this situation, but they were ineffective, as they quickly became inoperative and leaked badly due to the sludge fouling up their mechanisms and preventing their proper functioning.

When these conditions were recognized, the air relief valves were removed and replaced with manually-operated gate valves (Figures 1 and 2), the valves being piped to a vent line of the building drainage system. This relieved the situation, for the sludge lines can be bled of accumulated gas as required. These relief valves are left open when the unit is not in operation so as to prevent the accumulation and resulting pressure of gas formation. When the recirculation of sludge is again established, these valves are closed and normal operation ensues.

Sludge Thermometers

Another problem has been the use of immersion-type thermometers for sludge temperature determination. This type of thermometer generally consists of a bulb inserted through a tapped opening in the pipe, with the bulb at right angles to the flow of the sludge and projecting into the liquid to some degree.

Such an installation has been found to result in the projecting bulb accumulating debris, which will cause partial stoppage in the line. When the stoppage becomes large enough, sufficient pressure is built up on the pump side of the stoppage so that the bulb is bent or broken, the indicator

becomes useless, and dismantling of the piping or equipment usually is necessary to clear the stoppage. If such damage doesn't occur to the thermometer, then the build-up of debris on the thermometer bulb will insulate it to the extent that true temperature indication is impossible.

The ideal type of installation for a bulb-type thermometer would be one in which the bulb is inserted as close to the inside face of the pipe as possible and is pointed in the direction of flow of the liquid. As there apparently is no standard bulb-type thermometer which permits such an installation, then the next best method would be to install the bulb at right angles to the direction of flow but tangential to and as close to the inside circumference of the pipe as is possible. A protective sheath that can be removed for cleaning should encase the bulb to prevent it from becoming damaged.

In the cases of both hot-water and sludge temperature indicating equipment, consideration must be given to locating them a reasonable distance away from the heat exchanger.

It is also advisable to have in the line a section of non-heat-conducting pipe, or, if the piping is of flanged design, to insert one or two rings of non-conducting material, such as asbestos or formica, between adjacent flanges in the pipeline. These insulating rings should be at least 2 in. thick. Experience has shown that heat from the water jacket can be transmitted through the pipe to the indicators (Figures 1 and 2) and false readings will result. This is important, because the differential temperatures encountered in the normal operation of a sludge heat exchanger are usually of comparatively few degrees and a slight error in temperature recording will result in a large percentage of error when computing the thermal efficiency of the unit.

Setting of Units

The method of setting the heat exchangers should also be carefully stud-

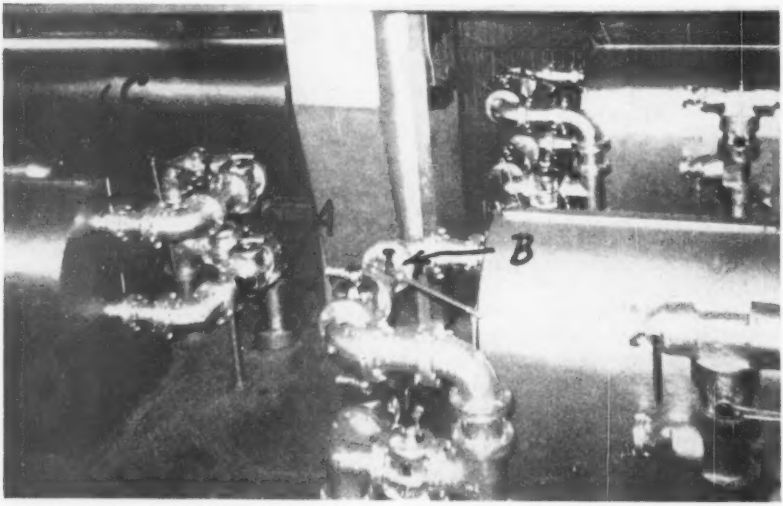

FIGURE 1.—General view of sludge heat exchanger equipment showing: (A) original location of the temperature bulb that, operating through a thermostat (C), actuated a remote solenoid valve to open and close the hot-water supply; and (B) the tap and manually-operated air and gas bleeder valve.

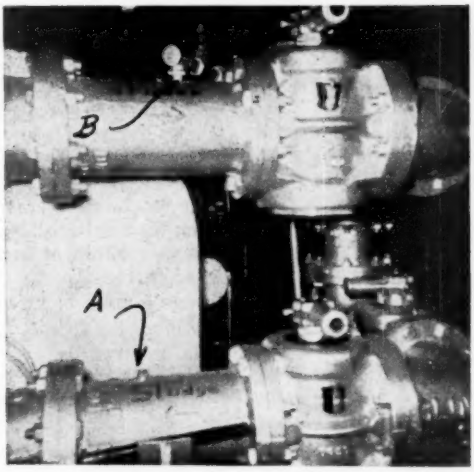

FIGURE 2.—Detail of thermometer and bleeder valve location shown in Figure 1.

ied to be sure that any space beneath the unit is self-draining and readily accessible for cleaning. Because of the possibility of leakage or spillage, there is always the chance that liquid sludge can accumulate under the unit. Unless the spillage is properly flushed out, it will create a corrosive condition and a very odorous situation. This was found out the hard way at Columbus, where the condition had to be corrected shortly after placing the exchangers in use.

Caking and Liming

The units have not been in operation long enough to determine the frequency with which the units should be dismantled for cleaning the sludge piping. From observations to date, however, water temperatures up to 165° F. have had no adverse effect so far as sludge caking on the pipe walls is concerned.

Due to the comparative hardness of the Columbus water, however, it has been found advisable to treat the circulating water with a standard boiler compound to prevent accumulation of lime deposits. This practice has been followed for some time in order to protect the engine water jackets and piping. Inasmuch as the same water is used in the heat exchangers for heating purposes, it is expected to be equally effective in this respect.

Efficiency of Units

After experiencing and correcting the various difficulties set forth herein, a schedule of operating tests was prepared to determine the efficiency of the units. The results of these tests showed that efficiencies varied from 90 to 12 per cent in thermal conductivity, with no apparent reason for the wide divergence of the results.

Special care was used during each test to take readings after the exchangers had been in operation sufficiently long to eliminate any possibility of gas pockets and to approximate optimum test conditions as nearly as possible.

To analyze the results and draw definite conclusions is difficult because of variables, which, under normal operating procedure, are impossible to control. The measure of efficiency of the unit is, of course, the ratio between the amount of heat given up by the source

and the amount of heat gained by the medium being heated, in any unit of time of operation.

The time element can be very accurately determined.

The source of heat and the amount given up can be fairly accurately determined by means of the ingoing and outgoing water temperature indications and the metered volume.

With the heat recipient, which is the sludge, the whole determination is subject to so many variables that the results are questionable. In the first place, the only method available for measuring the volume of sludge passing through the unit is based on the rated capacity of the pump circulating the sludge. This capacity is subject to several variables, including the discharge head on the pump (varies with the changing level of the liquid in the digester to which it is pumped), the suction head on the pump (level in the raw sludge well), the solids content of the liquid being pumped, and the volatile solids content.

All these factors contribute to the possibility of error in the computations. In addition, the average sewage plant is not equipped to determine all these factors simultaneously and at the necessarily frequent intervals during a test run. It then becomes a matter of taking the results of several normal operating periods, adjusting the factors as closely as possible to fit the conditions obtaining in each case, and averaging the results. Under these circumstances a matter of personal judgment in adjusting the variable factors can change the picture considerably. Therefore, no definite statement is possible as regards efficiency of these units.

It is recognized that the results will vary from time to time and the only measure of proper or improper operation results, at least in the case under discussion, is going to be determined on a comparative basis. Comparative, in that the average of the results of operation for one period as compared to the results of operation of another period a month, six months, or a year later will determine the need for overhaul of the units.

II. Dayton Experience

By Resler H. Calihan

Assistant Superintendent, Sewage Treatment Plant, Dayton, Ohio

The arrangement for separate digestion of sludge at Dayton, Ohio, is as follows: There are six 50-ft. diameter digesters and four 85-ft. diameter tanks having a total capacity of 900,000 cu. ft., or 3 cu. ft. per capita. These units supplement six Imhoff tanks (capacity 429,000 cu. ft.) handling flows which average 42 m.g.d.

The small digesters, in operation since 1938, are equipped with internal heating coils, through which hot water is circulated from gas-fired boilers located in the pipe gallery. These units have given satisfactory performance since that time at temperatures between 80° and 90° F. However, as incrustation of sludge on the outside of the coils increased, water temperatures had to be raised above 130° F. to maintain proper heat transfer. Increasing the temperature accelerated incrustation and soon necessitated removing the tank from service, draining it of sludge and grit, and ventilating the interior before the coil cleaning job could proceed. Cleaning required one to three weeks. Failure of a water coil even has presented a condition in which sludge was circulated through the hot-water line.

Trouble also has been experienced

with this type of gas-fired boiler when excessive condensation of combustion products caused deterioration of the cast-iron boiler sections, the vents, and the insulation covering. These heating units have a capacity of 600,000 B.t.u. per hour. Although effective, they left at least three features to be desired—namely, automatic control of temperature, safe and economical operation of the equipment, and efficient repair and maintenance of the equipment.

New Heat Exchangers

To meet these requirements at Dayton, two external heat exchangers were installed in 1946 and two additional units were added in 1948, each to provide enough heat for an 85-ft. diameter digester.

The two original heaters did not have a device for automatic control of "digester sludge" temperature, but these accessory controls were added to the units in 1948. At present these controls are not critical enough for the desired close temperature operation and require frequent resetting by trial.

The heat exchangers are equipped with 190-g.p.m. centrifugal sludge pumps circulating through 4-in. lines at a velocity of 5 ft. per sec. The coils extend a total of 96 ft. within the water bath, making 16 passes before leaving the heater. The flow velocity has kept the sludge lines clean (Figure 1).

The temperature differential between inlet and outlet circulating liquor has averaged 3° F., but varies according to the solids concentration, the circulation rate, and the difference in temperature between it and the water bath. Permanent records are kept to show hours of operation, gas consumption, and temperatures on all contributing phases.

Bath temperatures are maintained between 130° and 155° F., whereas the temperature of the sludge in the digester is held at 96° F. with little difficulty. Fluctuations have occurred from time to time due to minor maintenance problems, but these conditions were soon corrected.

Each burner will consume 800 to 900 cu. ft. of gas per hour when burning, but the actual gas consumption averages less than 300 cu. ft. per hour. This rather low usage is due to the technique of feeding sludge at solids concentrations of 6 per cent or over, which on a volume-for-volume basis is less than 1 per cent feed ratio per day. On the other hand, the addition of volatile solids each day very closely approaches the accepted 5 per cent ratio of volatile solids feed to volatile solids content of the digesters. This concentration of solids does not lend itself readily to supernatant formation. Total supernatant withdrawal in 1951 amounted to less than 2 per cent of the quantity added to the digesters.

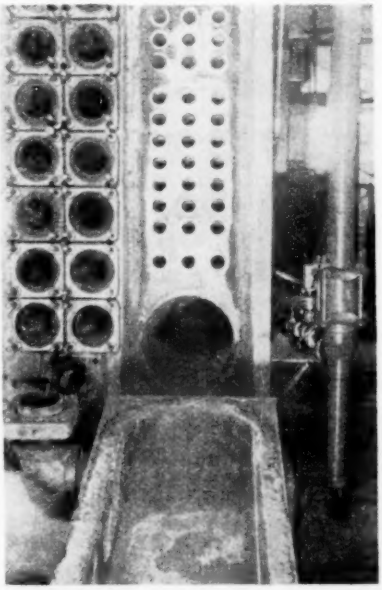

FIGURE 1.—Rear of heat exchanger opened to show arrangement of sludge tubes (left) and flue tubes (right).

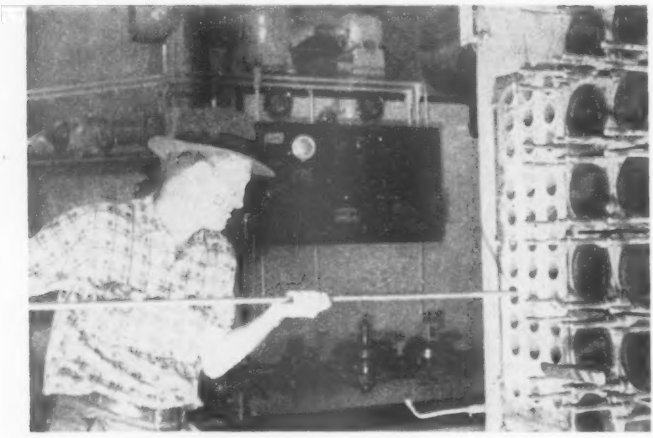

FIGURE 2.—Front of heat exchanger opened for flue tube cleaning. Electrical control board in background.

Operational Difficulties

The control unit has at several times caused anxiety and dismay, but usually when the burned-out tube was replaced the trouble disappeared. Installation of a larger transformer than originally called for in the digester gallery corrected another problem of fluctuating voltages, which had caused repeated failures of the sensitive control tubes.

Sludge caking on the interior of the sludge heating coils has been practically negligible, even after six years of continuous operation. The outside of the coils was found to have only a thin, black, soft film about 1/32 in. thick adhering to the metal surface.

The fire tubes (Figure 2) showed need for more frequent cleaning (every six months). Incrustation in the fire tubes had built up to ¼ in. with iron oxides, which flaked off rather readily when cleaned. Even under these conditions the heater was working effectively and, after a closer check of gas consumption, did not show any greater demand than the other (cleaner) units.

Sludge pump shafts used on one make of circulating pump used on the exchangers have shown excessive wear at the packing gland box, which necessitates replacement and repair. The shafts are then metal sprayed and machined back to proper size. The wearing condition is caused by sludge seeping through the packing to the bare metal shaft, with subsequent grinding effect. The use of a mechanical seal has been proposed to offset the effect of the shaft wearing. This is to be installed.

One other experience relating to heat exchange in digesters is one not often mentioned. On the floating covers of the digesters there is an air space between the metal roof structure and the wooden roof covering. So much condensation occurs under the wood that after a few years in operation the lumber crumbles and exposes the under structure to the elements. Replacement of these covers is quite costly and it would be interesting to learn if the problem is general, and how it might be corrected.

III. Akron Experience

By George S. Long

Chief Supervisor of Operations, Sewage Treatment Plant, Akron, Ohio

The sludge heating equipment put into operation within the year at the Akron, Ohio, sewage treatment works consists of eight digester heaters and external heat exchangers (Figure 1). Four of these heaters are series-flow and four are parallel-flow units. Of each group, two are gas fired and two are combination gas and oil fired. The sludge piping is so arranged that any combination of heaters from one to eight may be used to heat raw incoming sludge. The four parallel flow heaters also can be used in any combination to re-heat sludge by pumping it from a digester, through the heaters, and back to a digester. The piping and pumps in the control chambers are so arranged that sludge may be pumped from five different locations in a digester, through the heaters, and back to any of three different locations in the same digester or in any other digester.

On January 29, 1951, oil fires were started in the four combination heaters. Incidentally, January 29 was one of the coldest days of the winter. Work was continued until about 10:30 that night before it was certain that the burners would continue to function well enough to keep the building warm and not allow some of the piping to freeze. The trouble was due to the contractor having used ordinary pipe dope in putting the fuel oil lines to-

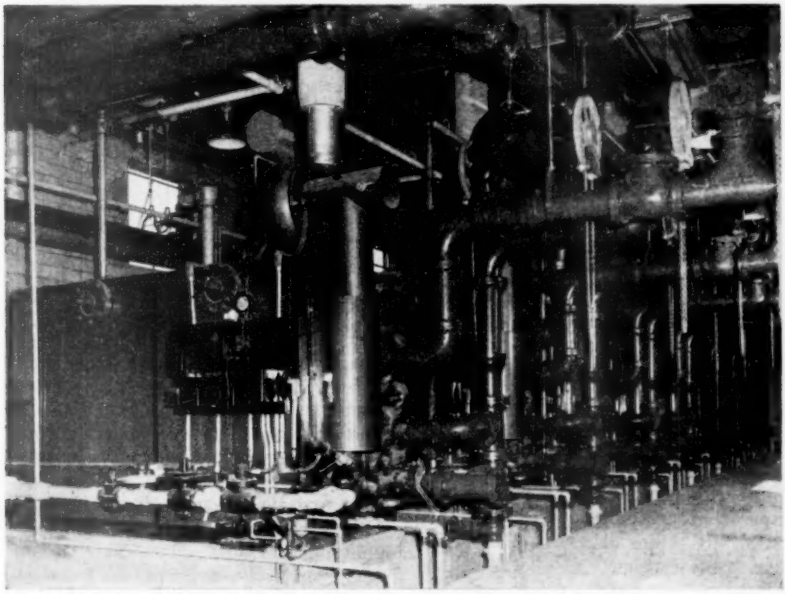

FIGURE 1.—Four series-flow and four parallel-flow external heat exchangers comprise battery installed at Akron, Ohio, during 1951.

gether. The oil dissolved the dope and the joints leaked.

Between January 29 and August 26 the digesters were filled and the sludge was circulated. The temperature increased to about 82° F., but the pH remained low. On August 26 and 27, 2,200 lb. of lime was added to digester No. 3. The pH rose to 8.4, but no combustible gas was given off and in about four days the pH dropped back below 7.

On September 11 burnable gas was given off by digester No. 3. The other tanks followed before the end of the month. When it seemed certain that combustible gas would continue to be produced, the gas burning equipment was put in operation. Later on, after the gas pressure vessel was purged and the controls on the gas boosters and compressors were adjusted, the gas burners were reset to operate at the boosted gas pressure.

From time to time there have been minor troubles with the heaters. In most cases the trouble has been due to the flame rod losing contact when the fuel changed from oil to gas. Occasionally, control contacts have failed to function.

No detailed studies of the efficiency of these heat exchangers has been made. They are rated at 1,000,000 B.t.u. per hour. The few observations which have been made on the parallel-flow heaters have indicated that with three heaters operating, the temperature of the sludge is raised between 2° and 3° F. during passage through the heaters. The sludge pumps are rated at 700 g.p.m. against 65-ft. head, but when used for circulating sludge the actual head is less than 40 ft. and the capacity is about 1,100 g.p.m. This would indicate a transfer of about 500,000 B.t.u. per hour. As the calorific value of the gas has not been determined, the over-all efficiency of the heaters cannot be stated at this time.

The exhaust fans on the heaters have a rated capacity of 2,000 c.f.m., so that with all eight heaters in operation air is being removed from the building at the rate of 16,000 c.f.m. This is a lot of air to heat during the winter. Also, when the windows are all closed the vacuum in the building makes it almost impossible to open an outside door. This condition is being relieved by installation of an auxilliary air inlet to each heater.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Reports on the Operation and Maintenance of the Easterly Sewage Treatment Plant, Cleveland, Ohio, for the Years 1949 and 1950 *

By John J. Wirts, *Superintendent*

General

Operating conditions and results during 1949 were quite similar to those experienced in previous years. Operating procedures were continued with only minor changes. The sludge line to the Southerly plant was cleaned four times during the year, with little trouble. An automobile equipped with a radio-telephone was found to be very helpful in this operation.

During 1950, major repairs and additions were made to the Euclid Creek pumping station. Two new 1,000-g.p.m. vertical sewage pumps were installed; also new 12-in. cast-iron gate valves on the ejector intake manifold.

* For last previous extract see *Sewage Works Journal*, **21**, 5, 902 (Sept., 1949).

Comminutors and Detritors

A new 54-in. comminutor was installed in July, 1949. During 1949, the four detritors removed a total of 108,823 cu. ft., or 76.5 per cent of the total grit removed by the plant.

In 1950, the two new 54-in. comminutors handled 22,350 m.g. of raw sewage during 11,571 machine-hours. This represented about two-thirds of both the total comminutor hours and the total estimated comminuted flow. Bearing trouble necessitated general overhaul of No. 1 and removal of No. 3 comminutor for replacement. Of the total of 1,456 teeth replaced during the year, 1,146 were in comminutors No. 1 and 2 and the remaining 310 in comminutors No. 3 and 4. The rake blades on detritors No. 1 and 2 were replaced and new bushings were installed in the rake joints. All ironwork was scraped and painted before the units were returned to service. The four detritors removed 100,062 cu. ft., or 83 per cent of the total grit removed from the raw sewage.

Screens and Grit Chambers

During 1949, this equipment was used chiefly during storm flow periods and handled about one-seventh of the total raw sewage flow. Cloroben was experimented with for odor control on the grit dump area, and found to be very effective. A combination use of Cloroben and some chlorinated lime seems justified for future use.

During 1950, the grit chambers handled about one-sixth of the raw sewage total flow, mostly during storm flows. On four occasions grit chambers were cleaned, six channels at a time, making a total of two complete cleanings per chamber. More frequent cleaning of channels is indicated, which would make it desirable to investigate the cost of grit removal by pumping.

Primary Settling

Wasting of excess activated sludge to the raw sewage entering the primary tanks was continued throughout 1949, and was done during the lower flow periods of the day as much as possible. An apparent suspended solids reduction of 37.6 per cent took place in the primary tanks, as compared to 33.7 per cent during 1948.

Pumpage of waste activated sludge into the raw sewage was discontinued in March, 1950. The reduction in suspended solids rose to between 45 and 50 per cent, with an average of 47 per cent for the year. Cross collector chains on tanks No. 2 and 3 were partially replaced. In tank No. 2 evidence indicated that the cross collector chain had jumped off the lower sprocket several weeks before broken shear pins indicated any trouble.

Distribution of air to the northern half of the central channel was increased by flushing away much of the grit covering the plate diffusers and then breaking the plates. The grit was allowed to flush out through the by-pass. This channel cannot be dewatered for cleaning and repairs to the diffusers without by-passing both primary and secondary treatment processes.

Aeration Tanks and Blowers

During 1949, steel aeration frames and cleaned diffuser plates were installed in tanks 1, 2, 4, 5, and 16. In tanks 8 and 15 the aluminum air manifolds were not replaced, but new diffuser plates were installed. The large air blowers were operated under throttled conditions the greater portion of the year. Blower discharge pressures have remained in the normal range of 7.3 to 7.6 p.s.i., due to the regular diffuser plate cleaning program.

Air delivery was reduced by 5,000 c.f.m. in April, 1950, and was further reduced in November by limiting air production to a single 40,000-c.f.m. blower, a reduction of about 40 per cent. This limitation reduced electrical consumption of the blowers by 35

TABLE I.—Summary of 1949 and 1950 Operating Data, Easterly Plant, Cleveland, Ohio

Item	Average 1949	Average 1950
Raw sewage flow (m.g.d.)	102.1	108.3
Settled sewage flow (m.g.d.)	99.7	99.8
Grit removed (cu. ft. per m.g.)	3.82	3.04
Screenings removed (cu. ft. per m.g.)	0.33	0.26
Suspended solids (p.p.m.):		
Raw	256	267
Settled	159	142
Effluent	25.6	22.8
Per cent removed	89.8	91.5
B.O.D. (p.p.m.):		
Raw	200	178
Settled	107	109
Effluent	9.8	12.2
Per cent removed	95.2	93.1
Oxygen consumed (p.p.m.):		
Raw	98	100
Settled	69	69
Effluent	19	25
Per cent reduction	80.2	74.5
Dissolved oxygen (p.p.m.):		
Raw	1.3	2.0
Aerator influent	1.2	2.1
Aerator effluent	3.8	4.5
Final effluent	4.9	3.9
Ammonia (p.p.m.):		
Raw	10.7	11.3
Settled	5.1	6.9
Effluent	2.4	7.2
Nitrite, effluent (p.p.m.)	0.64	0.7
Nitrate, effluent (p.p.m.)	3.8	1.3
Sludge pumped to Southerly plant, total (m.g.)	213.78	216.82
Per cent moisture	96.6	96.9
Activated sludge:		
Total solids (p.p.m.)	6,760	5,950
Volatile solids (%)	64.3	61.4
Mixed liquor susp. sol. (p.p.m.)	1,480	1,380
Sludge index (ml./gram)	97	99
Air (cu. ft./gal. sett. sew.)	0.82	0.84
Postchlorination:		
Days applied, total	89	86
Application rate (p.p.m.)	4.0	3.8
Residual maintained (p.p.m.)	0.5	0.8
Bacterial count: agar plates at 37½° C. (1,000 per ml.):		
Raw	2,300	3,100
Effluent	120	340
Chlorinated effluent	0.37	0.27
Per cent reduction	99.9	99.99
Presumptive *B. coli* (1,000 per ml.):		
Raw	170	130
Effluent	2.3	3.5
Chlorinated effluent	0.01	—
Per cent reduction	99.9	—
Plant costs ($ per m.g.):		
Operation and maintenance	19.72	16.55
Administration	3.51	4.41
Total	23.23	20.96

per cent. Actual saving in power amounted to $9,605 for the last six months of 1950 as compared with the same period of 1949. It is possible that the Easterly plant can produce an effluent somewhat inferior to the activated sludge effluent, but at a considerable power saving.

Coincident with the reduced air consumption the iron content of the raw sewage increased to 24 p.p.m. average for the year, as compared with 18.5 and 20.2 p.p.m. for 1948 and 1949, respectively. In theory, a diffused air plant cannot handle this quantity of iron; certain plants have been forced to shut down because of similar iron salt loadings. However, the distribution and character of the iron wastes may be suitable for oxidation and precipitation similar to a chemical treatment plant. The expected increase in sludge index with reduced air (at times dissolved oxygen has been absent) has not taken place. A comparison of quantities shows 1.09 cu. ft. of air used per gallon in December, 1949, with sludge index of 85, and 0.62 cu. ft. of air used per gallon in December, 1950, with sludge index of 87.

During 1950, cleaned diffuser plates were installed in tank No. 3. The steel plate holders were inspected and it was found that much of the paint had failed. The aluminum plate holders in tanks 6, 9, 10, and 13 were removed and replaced with welded steel holders.

Twelve leaks at mechanical couplings in the main air lines were stopped by replacing the rubber gaskets, which were without life and had hardened to such a degree that they possessed little sealing capacity or flexibility. Replacement of approximately 100 gaskets is required to stop air leakage, which adds perhaps $5,000 to the annual power cost.

Operation data for 1949 and 1950 are summarized in Table I.

Reports on the Operation and Maintenance of the Westerly Sewage Treatment Plant, Cleveland, Ohio, for the Years 1949 and 1950 *

By John O. Barrett, *Superintendent*

General

The population equivalent of wastes handled by the plant is about 400,000, whereas the actual population served is only slightly more than one-half that number. During 1949, all previous flow records were broken with a total flow of 12,459 m.g., only to be surpassed in 1950 with 13,860 m.g. The maximum monthly flow ever recorded occurred in March, 1950, with 1,374.4 m.g. (an average of 44.3 m.g.d.) entering the plant.

Grease Aeration Channels

The grease aeration channels, which were provided with perforated pipe for air distribution in 1948, were operated as secondary grit channels. They proved valuable in removing considerable fine grit and sand, which is pumped to the detritors and removed in the usual manner. Due to the difficulty of removing large quantities of grit, a monthly cleaning schedule was adopted.

Sedimentation

Although a rigid schedule for poking of the Imhoff tanks was followed, the slots frequently became blocked, particularly during the winter months. When this occurred the affected tanks were pumped down and the slots were washed. No. 13 Imhoff tank, used for sludge storage, was found to contain several tons of grit, which was removed. All gas vent scum was washed

* For last previous extract see *Sewage Works Journal*, **21**, 5, 905 (Sept., 1949).

to the sludge storage tank instead of being added to the digesters. An additional Imhoff tank was used for sludge storage.

Incineration

Only minor repairs were necessary to the incineration equipment, as an increased demand for filter cake for soil conditioning purposes has seriously reduced the need for using the equipment.

The ash line was cleaned as needed with muriatic acid or by rodding. A length of horizontal pipe and a sharp bend were eliminated in the ash line as it leaves the incineration building. Also, a brick vault was built on the outside of the building to make easier change-over of lines possible for diverting the ash slurry flow when the line became blocked.

Table II is a summary of operation data for 1949 and 1950.

TABLE II.—Summary of 1949 and 1950 Operating Data, Westerly Plant, Cleveland, Ohio

Item	Average 1949	Average 1950
Raw sewage flow (m.g.)	34.1	38.0
Grit removed (cu. ft. per m.g.)	3.03	2.97
Per cent volatile	21.0	19.6
Suspended solids (p.p.m.):		
Raw	265	252
Imhoff tank effluent	184	174
Per cent removed	30.2	30.6
B.O.D. (p.p.m.):		
Raw	249	219
Imhoff tank effluent	198	172
Per cent removed	20.5	21.2
Oxygen consumed (p.p.m.):		
Raw	164	148
Imhoff tank effluent	144	130
Per cent reduction	12.5	12.1
Total bacteria (1,000 per ml.):		
Raw	1,251	1,319
Imhoff tank effluent	675	556
Presumptive *B. coli* (1,000 per ml.):		
Raw	315	404
Imhoff tank effluent	85	130
Prechlorination:		
Days operated	86.2	90.4
Average dose (p.p.m.)	7.54	6.31
Postchlorination:		
Days operated	78.7	79.0
Average dosage (p.p.m.)	7.24	7.24
Average residual (p.p.m.)	1.1	1.36
Raw sludge to digesters:		
Number of additions per month	75	77
Temperature (° F.)	62	62
Volatile solids (%)	65.1	64.5
Total solids (%)	6.55	6.42
pH	6.2	6.5
Alkalinity as $CaCO_3$ (p.p.m.)	800	770
Digester supernatant:		
Total solids (%)	0.91	0.97
Volatile solids (%)	53.4	52.3
pH	8.1	8.0
Alkalinity, as $CaCO_3$ (p.p.m.)	2,560	2,550

TABLE II.—Summary of 1949 and 1950 Operating Data, Westerly Plant, Cleveland, Ohio—Continued

Item	Average 1949	1950
Gas production:		
Daily production (cu. ft.)	170,700	174,800
Cu. ft per lb. volatile solids	8.4	7.9
CO_2 (%)	31.2	29.7
Utilization of digester gas:		
Digester heaters (%)	26.4	29.5
Building heaters (%)	18.5	14.6
Incinerators (%)	25.2	25.4
Wasted (%)	29.9	30.5
Digested sludge vacuum filtered:		
Total solids (lb. per month)	462,100	463,300
Total solids (%)	7.52	7.99
Volatile solids (%)	51.4	49.2
pH	8.0	8.0
Alkalinity, as $CaCO_3$ (p.p.m.)	2,410	2,550
Chemical dosage for vacuum filtration (%):		
Ferric chloride	3.39	3.00
Lime	15.5	15.4
Calcium oxide	14.0	13.9
Sludge filtration:		
Filter cake:		
Moisture (%)	64.9	64.4
Volatile solids (%)	45.2	—
Pounds dry solids per sq. ft. filter area per hr.	3.58	3.44
Filter cake per filter hour (tons)	0.84	0.80
Average filter cloth operating life (hr.)	196	208
Sludge filter cake incineration:		
Tons per month incinerated	273	226
Tons per incinerator hour	1.20	1.24
Tons used for soil conditioner	7,135	7,044
Fuel oil used:		
Gal. per ton of filter cake	0.078	0.047
Gal. per ton of dry solids	0.218	0.128
Gas used:		
Cu. ft. per ton of filter cake	684	841
Cu. ft. per ton of dry solids	2,026	2,305
Plant costs ($ per m.g.):		
Operation and maintenance	14.21	12.05
Administration	3.50	4.40
Total	17.71	16.45

Reports on the Operation and Maintenance of the Southerly Sewage Treatment Works, Cleveland, Ohio, for the Years 1949 and 1950 *

By Walter E. Gerdel, *Superintendent*

General

Grit volume during 1949 averaged 1.33 cu. ft. per m.g., or about two-thirds the quantity removed during the two preceding years. In 1950, however, the grit volume increased to 2.22 cu. ft. per m.g., as a result of closer control of grit chamber velocities.

Full time supervision was provided from January, 1949, on, utilizing available supervisory personnel and obtaining additional shift supervisory personnel as possible. No radical changes were made in operating methods during 1949, although there was a deter-

* For last previous extract see *Sewage Works Journal*, **21**, 5, 908 (Sept., 1949).

mined effort during 1950 to study in detail the various processes and procedures with a view to standardizing and improving them.

The underground sewage conduit leading to the Imhoff tanks had become badly disintegrated, necessitating repairs during October, 1949.

Foaming difficulties with the Imhoff tanks were prevalent during the summer months and considerable labor was expended on coping with this nuisance.

TABLE III.—Summary of 1949 and 1950 Operating Data, Southerly Plant, Cleveland, Ohio

Item	Average 1949	1950
Rainfall (in.)	35.39	48.64
Raw sewage flow (m.g.d.)	40.2	38.6
Screenings (cu. ft. per m.g.)	0.50	0.49
Grit (cu. ft. per m.g.)	1.33	2.29
Per cent volatile	39.8	33.1
Abbreviated aeration unit:		
Flow (m.g.d.)	19.1	20.6
Per cent of total flow	47.2	52.5
Air used (cu. ft. per gal.)	0.56	0.48
Trickling filters:		
Flow (m.g.d.)	20.2	15.9
Per cent of total flow	49.6	40.5
Suspended solids (p.p.m.):		
Raw	207	190
Imhoff tank effluent	113	114
Dorr tank effluent	19	21
Filter influent	113	114
Filter effluent	—	133
Final effluent	77	72
Dissolved oxygen (p.p.m.):		
Raw sewage	5.1	5.7
Imhoff tank effluent	2.1	2.1
Dorr tank effluent	2.6	2.8
Filter effluent	3.9	3.6
Plant effluent	4.5	5.1
River above plant	8.4	8.9
River below plant	7.5	8.4
B.O.D. (p.p.m.):		
Raw	128	121
Imhoff tank effluent	59	64
Dorr tank effluent	12	13
Trickling filter effluent	—	56
Final effluent	40	32
River above plant	16	8
River below plant	27	16
Oxygen consumed (p.p.m.):		
Raw sewage	76	81
Plant effluent	41	47
Final effluent	90	93
Sulfates in raw sewage (p.p.m.)	139	114
Imhoff tank sludge:		
Total solids (%)	7.2	8.3
Volatile solids (%)	45.0	42.8
Sludge drying beds:		
Per cent Imhoff tank sludge dried	8.3	19.7
Moisture content dried sludge (%)	57.6	49.3
Digester operation:		
Raw sludge:		
Volume, total (m.g.)	238.24	245.14
Per cent from Easterly plant	82.9	87.4
Per cent from Southerly plant	17.1	12.6
Dry solids (mil. lb.)	66.3	62.9
Volatile solids (mil. lb.)	42.6	38.7

TABLE III.—Summary of 1949 and 1950 Operating Data, Southerly Plant, Cleveland, Ohio—Continued

Item	Average 1949	1950
Digested sludge:		
Volume (m.g.)	35.7	34.0
Dry solids (mil. lb.)	20.4	18.3
Volatile solids (mil. lb.)	9.1	8.1
Total solids (%)	6.9	7.0
Volatile solids (%)	44.6	44.3
Alkalinity (p.p.m.)	3,270	3,240
pH	7.4	7.5
Supernatant:		
Volume, total (m.g.)	207.3	215.0
Total solids (p.p.m.)	14,899	13,800
Volatile solids (p.p.m.)	8,209	7,093
Suspended solids (p.p.m.)	—	12,265
Gas production:		
Volume (1,000 cu. ft. per day)	917.8	775.7
Cu. ft. per lb. vol. solids	7.4	7.4
Per cent CO_2 in gas	30.6	31.2
B.t.u. (gross)	631	599
Gas utilization (per cent):		
Wasted	34.0	29.3
Digester heating	28.9	33.6
Incinerators	15.1	9.6
Gas engines	15.1	18.1
Building heat and misc	6.9	9.5
Vacuum filtration of sludge:		
M.g. filtered, total	46.3	40.4
Mil. lb. dry solids, total	26.9	23.1
Chemicals used (%):		
Ferric chloride	4.40	4.60
Lime	14.40	15.50
CaO	12.90	14.04
Filter cake production:		
Tons dry solids, total	18,827.6	16,281.2
Per cent solids	29.0	29.2
Filter rate (lb. dry solids per hour per sq. ft. filter area)	3.18	3.13
Filter cloth life (hours)	334	373
Sludge incineration:		
Sludge cake (tons)	55,336.5	53,387.8
Sludge cake (tons per incinerator hour)	3.15	3.29
B.t.u. per lb. vol. solids	12,014	11,032
Filter cake moisture (%)	71.0	70.8
Filter cake per cent volatile	41.0	39.1
Plant costs ($ per m.g.):		
Operation and maintenance	14.61	16.92
Administration	3.52	4.42
Total	18.13	21.34

Alternate resting of the tanks (as many as six foamed badly simultaneously) helped, although cleaning up the tank surfaces was aided by use of a portable high-pressure pump rig utilizing Imhoff effluent.

Gas Engines and Blowers

No major overhauls were necessary during the two-year period. Each engine was operated on a different test oil lubricant to obtain comparative data. Oil consumption had increased, however, to the point where major engine overhauls would be necessary during 1951. Several times during 1949 the engines failed during operation or could not be started, generally due to minor maintenance needs, such

as bad spark plugs, air distribution, and ignition troubles.

Trickling Filters

Extensive pooling of the filters persisted, the badly clogged condition of the stone being only partly relieved at the surface where it could be poked and rodded. The condition of the filters is such that serious consideration should be given to a major project of removing, cleaning, screening, and replacing all of the stone if future operation of the Southerly plant is to include this unit as an essential part of the treatment process. Extensive concrete repairs are needed on the dividing walls, along with other general repairs. The necessity of fine-screening the Imhoff effluent before applying it to the trickling filters resulted in by-passing the filters whenever it was necessary to clean the fine screens.

Sludge Concentration Tanks

The concentration tanks during 1950 received 214.25 m.g. of mixed fresh solids, skimmings, and excess activated sludge from the Easterly plant. The sludge mixture, as received, averaged 3.09 per cent total dry solids and was transferred to the digestion tanks without further concentration. Comparable figures for 1949 were 215.37 m.g. and 3.38 per cent.

Southerly excess sludge amounting to 49.01 m.g. in 1950 was reduced in volume about 40 per cent by concentration to 2.70 per cent dry solids, with supernatant returned to the raw sewage flow averaging 909 p.p.m. dry solids. This compared with 1949 values of 44.48 m.g., 3.01 per cent, and 860 p.p.m., respectively. The 1949 excess sludge volume had increased about 100 per cent over the previous two years, probably due to the closer control and improved effluent of the aeration unit.

During March, 1949, a second concentration tank was set aside for only Southerly excess sludge. Also, the necessary piping was installed to use the existing permanent pumps for removing concentration tank supernatant. Previously, this had been done with a suspended portable pump and a hose. The new installation gave much closer control and better operation of the concentration units.

Odors in the concentration building continued to be disagreeable and objectionable, although by-passing of the Easterly sludge line directly to the digesters is expected to relieve the condition.

Sludge Digestion Tanks

Starting in September, 1949, all of the digesters were pumped down in turn, the heating coils were cleaned, and the grit was removed. In 1950 the digesters of Unit A were continued on a 4-ft. fill basis, whereas those of Unit B were changed to 3-ft. fill at more frequent intervals. Results showed no appreciable benefits from the changed schedule.

Operation data for 1949 and 1950 are summarized in Table III.

PRACTICAL METHODS FOR IN-PLANT REDUCTION OF METAL FINISHING WASTES *

By W. L. Pinner

Manager of Research and Development, Houdaille-Hershey Corp., Detroit, Mich.

In introducing the subject of metal finishing wastes reduction it is both appropriate and pertinent to quote the foreword of a recently published manual (1) compiled by the Metal Finishing Industry Action Committee of the Ohio River Valley Water Sani-

* Presented at 1952 Annual Meeting, Michigan Sewage and Industrial Wastes Assn.; Traverse City, Mich.; May 19–21, 1952.

tation Commission. The manual states: "It is a happy circumstance when pollution abatement and operating economies can be achieved from the same effort, yet that is exactly what can be accomplished if metal plants practice the good housekeeping principles set forth in this manual."

It must be obvious to anyone, be he associated with the metal finishing industry or not, that the salvaging of processing solutions for further use provides a lucrative means of achieving economy, providing, of course, that such a procedure is otherwise compatible with over-all operating costs. It is equally obvious that the salvaging of processing solutions involves retention of valuable materials in the places where they will perform useful service rather than finding their way into waste waters or other places of discard. The foregoing constitutes briefly the background of the subject to be presented and it remains to point out ways and means that have proved useful in achieving the desired results.

A case history may well serve to illustrate certain pertinent points. The situation to be described existed some years ago in an operation involving the plating of chromium on a production of 20,000 automobile hub caps daily. For the purpose, a so-called "hand-operated" unit was employed in the operation, in which six hub caps, mounted on proper fixtures, were handled at a time through the various cleaning tanks, the chromium plating tank, and the rinses following it.

It had been the practice in this particular operation to move rapidly from the chromium plating solution into a rinse, which was quite small, and then into a second hot-water rinse, the heat from which caused the parts to dry. To effectively remove the chromic acid from the plated parts it was necessary to run water at a very rapid rate through the first small rinse tank, since it became quickly contaminated, rendering the second rinse ineffective and thus causing an unsightly appearance to the supposedly finished parts. For the production of the 20,000 hub caps, that particular plant was using approximately 500 lb. of chromic acid daily. Furthermore, that plant was faced with the necessity of recleaning many of the parts from chromic acid stain.

Drip Rack

Failing at first to persuade management to install more efficient rinsing facilities, the first expedient involved placing above the chromium plating tank a simple bar on which the operator hung the plating fixture before moving it into the rinse tank. The parts, as they hung on this bar, dripped considerable quantities of chromic acid back into the processing tank, such that the usage of chromic acid abruptly dropped from 500 lb. to about 200 lb. per day. Quite unexpectedly, the plating tank operator was favorable to the arangement, claiming that it allowed him to rest his arm and created less fatigue than was the case with a continuous movement from the plating tank into the rinse tank.

The situation was not yet solved, however, because it soon became evident that the chromium plating solution was increasing in volume. This was due to the obvious fact that reclaimed solution was running back into the tank from the work, whereas the same amount of water was being dragged into the processing tank from the rinse preceding it. This led to the necessity of installing a drainage station for the preceding rinse water, after which things proceeded again on an even keel.

Further Re-Use

Aroused to the validity of the claims made for salvaging solution, the department was subsequently changed to include larger rinse tanks, through which it was unnecessary to run such large quantities of fresh water. Also, there

was added to the entire picture the system of returning this rinse water to the chromium plating solution. At its completion, the usage of chromic acid for this operation dropped to less than 100 lb. per day. The net saving of approximately 400 lb. of chromic acid, on this relatively small operation, resulted in material savings, which at today's prices would amount to more than $150 daily. Pertinent to this discussion is the fact that more than 400 lb. of chromic acid were retained each day for useful purposes and did not reach the sewer system.

A waste survey of this operation as it had existed probably would have revealed the presence of chromic acid in the diluted waste water in an amount exceeding that judged acceptable. In the revised plant, with the dilution occurring in this and other departments, it is probable that the concentration of chromic acid may have been tolerable.

The foregoing case is cited as an illustration of the economy to be effected by what is called "good housekeeping," while at the same time achieving the abatement of waste-water pollution. The basic principles illustrated are those of proper work drainage, proper rinsing, counter-current extraction of valuable chemicals, and judicious use of other equipment to make the application of these principles effective.

Racks and Position of Parts

There are many other factors in the operation of a metal finishing department, such as plating, anodizing, pickling, etc., which facilitate the application of these basic principles. For example, in a plating operation the plating racks themselves should be as free as possible from areas of built-up plated metal which will serve to trap solution and thus render rinsing difficult. Here again an economy is achieved in that built-up plating fixtures may sometimes require as much if not more current, and take as much if not more plate than do the "in process" parts themselves. Plating racks are, therefore, advisedly kept in good condition and will contain a minimum of exposed metallic surfaces.

The position occupied by the racked parts is important. Such parts should be placed in position so that the carry-over of solution from one tank to another is kept at a minimum. Not only will this prevent the unnecessary loss of solution, which might find its way into the waste waters, but again economy is introduced on the basis that those solutions are salvaged for further use and, perhaps even more importantly, will not be carried over as an impurity into subsequent baths.

Sometimes the design of parts makes it difficult to avoid solution dragout. In some cases a small hole placed in such cupped areas may be permissible and should be included in the design so as to permit proper drainage. At times other factors, well known to the electroplater, may make it necessary to rack parts in a position where drainage is difficult if not impossible. These factors, for example, may include what the electroplater calls proper plate distribution; or it may be necessary to rack the parts in an awkward position as far as drainage is concerned in order to obtain actual coverage due to what the electroplater calls throwing power. In such cases unusual losses and unusual contamination of processing baths may occur unless additional rinsing facilities are provided. In the light of critical metal shortages and in view of the emphasis being placed on stream pollution, industry might well adopt the use of additional rinses for purpose of achieving these good housekeeping principles.

All of the foregoing matters are discussed in somewhat greater detail in the manual referred to in the introduction of this paper.

In this booklet there also are discussed, in some small detail, further principles related to the abatement of stream pollution in reminding the electroplater that advances made in the knowledge of this subject permit the purification of processing baths which in the old days were discarded. Actually, in a large number of plating operations normally carried out, the necessity for discarding valuable plating solutions is the exception rather than the rule. Recent and current literature are literally filled with new processes by which contaminated baths can be purified and actually made, in some cases, as good if not better than newly prepared baths. Measures such as these properly fall within the scope of this discussion, although it is hardly proper to devote space in this brief presentation to detailed information which is adequately available to anyone seeking it.

Reference

1. "Plating-Room Controls for Pollution Abatement." Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio (July, 1951).

TIPS AND QUIPS

Disaster Scoreboard

Electrocution

On April 22, 1952, a three-day employee working at the Kincaid, Ill., sewage treatment plant was electrocuted when he came in contact with a charged water pipe. A fellow worker received a severe shock when he pulled the victim loose.

Oil Burner Fire

At Anna, Ill., a boiler for digester heating, converted to dual-fuel operation by the addition of oil burning equipment, failed to ignite properly. When the accumulated oil did ignite, the intense heat destroyed the boiler, but further damage was prevented by quick action of the operators.

Plant Fire

An estimated $12,000 damage was done to the Macomb, Ill., sewage treatment works on February 15, 1952, by a fire that destroyed the electric panel, records, and all first-floor equipment. The fire is believed to have been started by an overheated waste gas burner located in the chimney adjacent to the tile-covered wood roof of the service building.

Cause and Effect?

According to the August, 1952, issue of *The Digester*, more than 250 operators in Illinois have applied to the Sanitary Water Board of that state for certificates of competency, and nearly 200 such certificates have been issued. Some who have applied for but not received a certificate have not yet taken the required examination, and others are not yet eligible because they do not keep operation reports.

On the other hand, this last group may include some of those mentioned elsewhere in the same issue as being mystery fans—that is, submitters of reports with no signature or indication of which municipality they are from!

Do's and Don'ts for Chains and Chain Drives

Chains

1. Lubricate periodically. A lubricated chain will outwear a dry chain 15 to 1.

2. Clean regularly. Avoid rust, dirt, and grit at inter-link points—they cause excessive wear.

3. Don't permit kinks, twists, or knots. Don't permit a chain to cross an unprotected sharp corner or edge.

Don't trust chain that has been battered or bent.

4. Be sure hooks are properly seated.

5. Check welded rings and hook eyes periodically for cracks and distortion.

6. Anneal chain periodically and after it is subjected to heavy loads.

7. Remember that as the included angle of a sling is increased, its ability to support load decreases. Thus, a single chain supporting a load at its middle can handle as much as a double chain or chain sling of the same size that has an included angle of 120°. At 90° included angle, the two chains have a strength about 1.4 times that of one chain; at 60°, 1.6 times.

8. Know what the safe working load of each size of chain is, and don't exceed it. Remember that an old chain loses its strength to some extent.

Chain Drives

1. Keep drives entirely enclosed, if possible, to exclude dust. Dust and grit shorten chain and sprocket life.

2. Lubricate with oil or grease in the housing to well over one-half the drive height.

3. Keep sprockets and chain aligned. If guide links wear on one side, sprockets are out of line. If a motor drives one, check for excessive end-float on the shaft.

4. Don't use new chain on worn sprockets, or *vice versa*.

5. Keep sprockets tight on shaft.

6. Don't allow so much slack that the top strand rubs the bottom one or the chain can slip.

New Weed Killer

Newest of the chemical herbicides is CMU, developed by E. I. du Pont de Nemours and Company. This material kills all plant growth when applied in rates of 20 to 80 lb. per acre, is long-lasting in effect, may be applied in areas frequented by livestock, does not create a combustion problem when dried on foliage and clothing, is non-volatile, and does not tend to damage crops or shrubbery unless the root systems extend into the sprayed area.

Powerful Stuff

Sewers may conceal considerably more than meets the eye—or the nose. This is borne out by a report in the September 20 issue of *Life* regarding an illegal whiskey still discovered in a Claremore, Okla., sewer. The county sheriff and his men crawled in to wait for the moonshiners, but neglected to notify the local police. Citizens reported the investigators to the police, who stood watch at the sewer entrance. The result of the double all-night vigil? No moonshiners, but one of the sheriff's crew was bitten by a possum that lived in the sewer.

Among the several questions still plaguing us are:

1. Was the possum running the still?

2. Was the still placed in the sewer (a) for concealment, or (b) to facilitate waste disposal?

3. Was the possum sober or "under the influence"?

SEWAGE PLANT OPENINGS—The Joint Municipal Authority of Wyomissing Valley (Berks County, Pa.) invites applications for the positions of superintendent-chemist and chief operator at its new sewage treatment plant, now under construction and scheduled for completion about February 1, 1953. The 2-m.g.d. plant combines chemical treatment and high-rate filters. Starting salaries are: superintendent-chemist, $5,500 to $6,000; chief operator, $3,600 to $4,000.

Applications will be received until December 31, 1952. Application forms may be secured from H. F. Rickenbach, Secretary, Joint Municipal Authority of Wyomissing Valley, Borough Hall, West Reading, Pa.

Reviews and Abstracts*

Water Quality Criteria. California Water Pollution Control Board. (June, 1952).

This monumental research on water quality criteria is actually a compilation of all known standards of water quality as regards most beneficial uses and most contaminants, pollutants, and nuisances. The study, necessitated by provisions of the California Water Pollution Control Act, was made for the State of California Water Pollution Control Board by the California Institute of Technology under the direction of Professor J. E. McKee. The report contains 538 pages, plus 58 pages of appendices and 109 pages of bibliography.

Rigid standards for river basins and arbitrary zoning of streams or underground waters are ruled out by the directive that abatement requirements are to be based on the economics of waste treatment, as well as on the injury to existing or future beneficial uses of state waters. Therefore, regulatory authorities need as a guide data pertaining to limiting and threshold concentration of each potential pollution substance.

The report, therefore, is intended for use by the state and regional boards, and others concerned with water pollution control.

After giving introductory material and general considerations, the results of a literature search (a bibliography of 1,368 references substantiates the data presented) are presented under four main headings. The first is a compilation of water quality criteria as promulgated by state and interstate control agencies in the United States. The second is a review of judicial expressions pertaining to water standards, with instances where precise facts are lacking and more research is required to provide them. The third major heading lists the quality objectives for major beneficial uses of water, in as much detail as the reference material allows, including many sub-headings for each category. The major portion of the report is a listing of all the possible potential pollutants on which data are available.

A limited number of copies of the report is to be made available for general distribution by the State of California Water Pollution Control Board, Sacramento, Calif.

H. P. Orland

The Influence of Sulfite on the Methane Fermentation of Sodium and Calcium Acetates. By M. A. Noordam-Geldewagen, A. Manten, and F. M. Muller. *Antonie van Leeuwenhoeck*, **15**, 65 (1949).

This investigation was undertaken because monosulfite used in the production of cardboard from straw appears to interfere with methane production from the waste. Enrichment cultures were obtained by inoculating mud from a sewer or strawboard mill lagoon water into a medium containing 1 per cent sodium acetate and minerals with the exclusion of all oxygen, with repeated transfers into fresh medium. Asbestos was added to furnish artificial support for the organisms; substitution of ground chalk resulted in much lower rates of fermentation. The fermentation of sodium acetate was influenced by the pH of the medium, being greatest at 6.0 to 6.5. At pH 5.0 no fermentation occurred, possibly due to the undissociated acetic acid present at this pH, as fermentation started again when the pH was raised to 7.0.

In unbuffered cultures at an initial pH of 7.0 increasing concentrations of sodium sulfite retarded gas production; 100 p.p.m. had no effect, but 500 p.p.m. had a distinct inhibitory effect and 2,500 p.p.m. resulted in complete inhibition for 6 days. It was concluded that sodium sulfite had a bacteriostatic rather than a bactericidal action.

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

Studies were made of the effect of pH on the inhibitory action of sulfite on the fermentation of sodium acetate. At pH 6.0, 30 p.p.m. of sulfite gave a perceptible inhibition, 100 and 300 p.p.m. had greater effects, and 1,000 p.p.m. inhibited the fermentation completely for several days. At pH 6.5, 700 p.p.m. sulfite inhibited the fermentation completely, whereas 100 and 300 p.p.m. had retarding effects. At pH 7.0 the concentration of sulfite for inhibition was about three times and at pH 7.5 five times higher than at pH 6.5.

Attempts were made to find a means of eliminating the detrimental action of sodium sulfite by precipitation with calcium ions. A 0.1 per cent concentration of solid calcium sulfite was added to the medium buffered at pH 6.5, 7.0, and 7.5. At pH 6.5 and 7.0 calcium sulfite decreased the fermentation, but at pH 7.5 no inhibitory action of 0.1 per cent calcium sulfite could be observed. It was concluded that calcium sulfite had a similar though less pronounced effect than sodium sulfite.

Unbuffered calcium acetate medium fermented more rapidly than sodium acetate. Furthermore, fermentation of calcium acetate was affected by variations of pH from 5.5 to 7.0, as was fermentation of sodium acetate. This was attributed to the maintenance of favorable pH during the fermentation of calcium acetate as a result of formation of bicarbonate.

Addition of sodium sulfite to calcium acetate medium caused a marked retardation of fermentation even at 100-p.p.m. concentration. The inhibition gradually increased up to a concentration of 1,500 and 3,000 p.p.m. sodium sulfite, but even at the highest concentrations inhibition was not complete, as it was in the case of sodium acetate.

Inhibition of fermentation of calcium acetate with the addition of calcium sulfite was the same as that of sodium acetate and calcium sulfite.

In the waste liquor from a strawboard mill utilizing lime digestion the acetic acid (10 per cent of the total dry matter) will be in the form of calcium acetate, which will be readily fermented. Mills using both lime and sodium sulfite will have a pH of 6.5 and a concentration of even 100 p.p.m. of sodium sulfite may have an inhibitory effect on the fermentation. To counteract the detrimental effect of sulfite under these conditions it might be oxidized to sulfate by means of air, or reduced biologically to hydrogen sulfide.

H. HEUKELEKIAN

Summary Report on Water Pollution; Western Great Lakes Drainage Basin. U. S. Pub. Health Service Publ. No. 143 (1951).

This 11th in the series of 15 summary reports on major drainage basin areas of the United States covers the Great Lakes basin west of the Michigan—Ohio state line. Sewage and waste treatment projects estimated to cost $95,000,000 are recommended at 475 municipal and industrial locations in the area.

The projects needed include 294 for municipalities, many of which also handle industrial wastes, and 181 for industries. Municipalities need 187 new treatment plants, enlargements or additions to 84, and replacement of 23. Industry needs 104 new plants, enlargements or additions to 58, and 19 replacements. No projects are needed at 226 municipal and 187 industrial locations. There are 313 municipal sewage treatment plants in the basin, serving nearly 5,700,000 people, or 82 per cent of the population connected to municipal sewers. Of the separate industrial establishments listed, 36 per cent have some type of treatment facilities, although 27 per cent are reported as having inadequate capacity and 11 per cent as being improperly operated.

On July 1, 1950, the date of the report, 19 municipalities and 19 industries had treatment facilities under construction, and 176 municipalities and 98 industries were in the planning stage or had final plans approved. Since that date 43 treatment plants have been completed and placed in operation and 48 have been placed under construction. H. P. ORLAND

Determination of Nitrogen—Modified Kjeldahl Procedure Using Thiosalicylic Acid. BY PHILLIP MCCUTCHAN AND WALTER F. ROTH. *Anal. Chem.*, **24**, 369 (1952).

The determination of nitrogen in a nitrotype compound present in an industrial waste requires a special modification of the usual Kjeldahl procedure. Thiosalicylic acid is used to assist the conversion of oxidized nitrogen to ammonia.

R. S. INGOLS

Fourth Annual Review of Analytic Chemistry—Water Analysis. By S. K. Love and L. L. Thatcher. *Anal. Chem.*, **24**, 294 (1952).

A very complete review (references to 135 articles) of the broad subject of water analysis is given. Analytical techniques for many of the metal ions, as well as the usual materials of sanitary significance, are covered by this review. R. S. Ingols

A Report on the Symposium of Stream Pollution and Industrial Wastes at the A.A.A.S. Meeting in Philadelphia. *Chem. Eng. News*, **30**, 51 (1952).

A report on stream pollution analysis was given by Ruth Patrick, who emphasized that high concentrations of chemical contaminants destroy organisms normally present in river water. Russell E. Teague emphasized the increasing demand for cleaner streams and indicated that good progress was being made. R. S. Ingols

Ion Exchange Membranes Desalt Water with Ease. Anon. *Chem. Eng. News*, **30**, 898 (1952).

Ion exchange membranes and electrical energy are being put to work in a process for desalting sea water, brackish water, and industrial solutions. At present, there are no commercial or pilot plant installations, but the management of Ionics, Inc., Cambridge, Mass., claim that the cost of preparing industrial water from sea water by this method will be less than that for any other method.

In addition to its potential use in alleviating water shortages in many sections of the country, it can also be used to recover by-product chemicals and other materials from waste waters.

Batch operation of typical ion exchange columns is avoided by this new device. Power consumption is dependent upon the initial salt concentration. The exchange materials are in the form of sheets 0.25 to 1 mm. thick. In operation, the salt water is fed into the unit and water emerges in two streams; two-thirds of the initial water emerges salt free and the one-third contains the salt in concentrated form. The concentrated solution may be discarded or used for obtaining the concentrated elements. R. S. Ingols

Measurement of Toxicity of Substances to Fish. By D. W. M. Herbert. *Water and Sewage Eng.*, **2**, 11, 504 (Mar., 1952).

The relative merits of fixed volume tests *vs.* continuous flow tests in the measurement of toxicity of substances to fish are discussed. The main objection to fixed volume tests is that the presence of the fish in the water alters the properties of the solution. The continuous flow of water overcomes this objection, but is expensive and requires too much maintenance. The author suggests that the fish in fixed volume tests might be transferred to a fresh solution at intervals and the water might be oxygenated by a method which will not drive off volatile toxic agents too rapidly.

Also discussed are the various methods of expressing toxicity. It is important to know the lethal concentration of a poison over a long period of time; most methods are inadequate to determine this value, as they are based on relatively short periods of exposure and do not give the answer to the probable effect of lower concentration over a longer period of time. On the basis of 40 to 50 goldfish exposed at each concentration in the continuous flow apparatus, the author was able to examine more accurately the effect of concentrations below the theoretical threshold toxic concentration. It was shown that for cyanide the survival time was expressed by $C^n T = k$, where C is the concentration of poison in p.p.m., T is the median survival time in minutes, and n and k are constants. This relationship holds for cyanide concentrations below 0.25 p.p.m. In this range there is no threshold concentration, which means that the fish would die sooner or later if they were kept in it long enough. For other poisons, such as heavy metals, there probably is a threshold toxic concentration. Experiments lasting over much longer periods would be needed to determine such thresholds. Extrapolation of the straight-line relationship between the concentration of cyanide in logarithmic scale below 0.25 p.p.m. and the median time of survival would indicate, if such an extrapolation were justifiable, a survival time of 5 yr. at 0.023 p.p.m. cyanide concentration.

There is a very great variation in the resistance of a given species of fish of the same age, size, and reared under similar conditions to the effect of a given concen-

tration of a poison. This emphasizes the importance of using a great number of fish in a test. Frequency distribution of the number of fish overturning in successive equal intervals of time gives an asymmetric curve, but if time is expressed on a logarithmic scale the frequency distribution is more symmetrical.

H. HEUKELEKIAN

Industrial Waste Treatment at a Viscose-Rayon Factory. By J. W. HUGHES. *Surveyor*, **110**, 781 (Dec. 8, 1951).

The treatment system described is in use at a large, modern factory for pretreatment of the process waste before discharge to a municipal sewer. The total flow is greater than 3 m.g.d.

The drainage network is divided into four systems: storm, soil, acid, and sulfide. Storm drains discharge to a local brook. Soil drains, serving kitchens, lavatories, etc., pass into the main carrying treated works effluent.

The "acid" wastes include acid and soda rejects after recovery processes, floor and machine washings, alkaline liquors free of H_2S, CS_2, and Cl_2, wash waters from yarn processing, boiler blow-down, storm waters where acid or soda contamination is possible, and washings from water softening plants. Provision is also made for collection of all accidental acid or alkaline discharges. A typical average composition is of the order of 0.2 per cent H_2SO_4 and 1 per cent Na_2SO_4, with small quantities of Zn, Fe, cellulose, sulfur, and traces of H_2S. Periodic small discharges of saponified oils, dyestuffs, etc., also occur.

Treatment of the "acid" wastes consists of neutralization and settling. Solids are treated on drying beds or filter presses and dumped. Hydrated lime is used for neutralization; automatic pH control is employed. The treated effluent, which passes to the sewer, has a pH above 4. The sodium sulfate content is unchanged, but H_2S, Fe, and cellulose are reduced, and there is about 0.2 per cent of calcium sulfate.

The "sulfide" wastes are all alkaline, and consist of the combined discharges from yarn processing, floor and machine washings containing H_2S and CS_2, wash water containing free chlorine, and any other alkaline discharges where Na_2S or CS_2 may be expected. A typical average composition is about: 0.004 per cent H_2S, 0.01 per cent CS_2, 0.02 per cent NaOH, 0.05 per cent cellulose, together with carbonate, sulfate, and free sulfur in small quantities. Treatment is by biofiltration. Recirculation (2 to 1) is employed, the loading being 50 to 60 gal. (Imp.) of raw waste per cu. yd. There are no sedimentation tanks In the effluent, NaOH is absent and carbonate reduced, with corresponding formation of bicarbonate. The pH is between 8 and 9, and there are small quantities of sodium sulfate and thiosulfate, 1 p.p.m. of H_2S, 20 p.p.m. of CS_2, and 100 p.p.m. of cellulose. The effluent joins that from the acid treatment plant, and the mixture is chlorinated to reduce growth of fungi.

M. C. RAND

Trade Effluents and River Pollution. By J. MCNICHOLAS. *Surveyor*, **110**, 807 (Dec. 15, 1951).

Oftentimes, in building a new factory or expanding an existing one, no thought whatever is given to the disposal of liquid wastes until they begin to cause trouble.

The establishment of effluent standards not only restricts an industry's discharge of its wastes to streams, but may be expected to make municipal treatment plants unwilling to accept materials that make it difficult or impossible for them to meet the standards prescribed. By either means, the industry is likely to be called upon to provide at least partial treatment for its waste.

M. C. RAND

Disposal of Wastes from Water Purification and Softening Plants. A Committee Progress Report. *Jour. Amer. Water Works Assn.*, **43**, 11, 941 (1951).

Previous progress reports by this committee were abstracted in *Sewage Works Jour.*, **20**, 4, 779 (July, 1948) and THIS JOURNAL, **22**, 2, 275 (Feb., 1950). The investigation covers the following subdivisions: (a) filter plants and coagulation basins, (b) cation-exchange (zeolite) softening plants, and (c) lime and lime-soda softening plants. A final report has yet to be completed on filter and coagulation basin wastes, but no further study is contemplated on cation-exchange softener wastes. Both of these items were covered in the previous progress reports.

Lime and lime-soda softening plant wastes are reviewed again, as some additional progress has been made on this phase

of the problem. The great majority of these plants use ponding or lagooning and disposal in watercourses. Further information on utilization of calcium carbonate sludge as a precipitant in primary sewage treatment plants should be forthcoming from operation of the Daytona Beach, Fla., plant. The dewatering, drying, and pulverizing of this sludge for a variety of industrial uses is limited, as this method depends upon obtaining a permanent market for the dried material. The use of stationary kilns for calcining sludge from small water softening plants is still only in the experimental stage, as the one existing plant at Marshalltown, Iowa, has undergone many design changes in the past 10 years. A new type of rotary kiln has been under test at Lansing, Mich., but information is still lacking on its applicability to small softening plants. Large-scale sludge calcination with rotary kilns has been operating satisfactorily since 1949 at Miami, Fla., the first installation at a water softening plant in the United States.

ROBERT P. LOWE

The Effect of Ammonia Nitrogen and Hydrogen Sulfide on the Biochemical Oxygen Demand of Sewage. BY MEIR RIGBI. *Bull. Res. Council of Israel*, **1**, 1–2 (1951).

The effluent of an Imhoff tank gave as high a B.O.D. as the influent despite a 33 per cent decrease in suspended solids. The effluent showed, in addition, an increase in ammonia nitrogen and sulfides. It was assumed that failure to obtain a decrease in B.O.D. in the Imhoff tank was due to the increase in ammonia nitrogen and sulfides. (Reviewer's note: The possibility of other intermediate products of digestion getting into the flowing-through chamber by way of the slots was not considered.) Upon addition of ammonia nitrogen to sewage an increase in 5- and 7-day B.O.D.'s was noted. The increase in B.O.D. in 2.5 days due to the addition of ammonia nitrogen was lower. The author concludes that the addition of ammonia nitrogen increased the growths and multiplication of sewage bacteria and thus increased the B.O.D., despite the fact that control sewage had apparently 50 p.p.m. of ammonia nitrogen with a B.O.D. to N ratio of 12 to 1. (Reviewer's note: A more likely explanation of the results might be the increased oxygen demand due to the nitrification of ammonia.)

The addition of about 80 and 500 p.p.m. H_2S to sewage decreased the B.O.D. over 10 p.p.m. addition. Above 1,000 p.p.m. H_2S, B.O.D.'s increased. (Reviewer's note: It is not clear whether proper modifications were introduced to determine D.O. in the presence of such large amounts of H_2S.)

H. HEUKELEKIAN

The Effect of Excreta on Aluminium and Its Alloys. BY R. BUTLER AND E. W. SKERREY. *Water and San. Eng.*, **2**, 12, 539 (1952).

The effects of human and animal excreta on aluminum and its alloys were investigated for a period of 3½ yr. Tests were conducted with a number of aluminum alloys (as sheets, extrusions, and rivets), together with copper and mild steel sheets. These naterials were exposed under natural conditions in (a) a factory sewage farm, (b) a factory latrine, and (c) a cattle barn, under extremely severe conditions of service. The aluminum was partially immersed to make the conditions more severe than if completely immersed.

The results indicate that although slight corrosion may occur in aluminum in sewage plants, with suitable design it would not be of practical importance. Anodizing has been very beneficial in the absence of abrasion. The best aluminum alloys compared favorably with 99.95 per cent purity copper and were markedly superior to mild steel. In general, human excreta appeared more corrosive than cattle excreta, although an appreciable proportion of the attack in the latrine tests was due to flushing water.

H. HEUKELEKIAN

Infrared Spectrophotometric Determination of Oil and Phenol in Water. BY R. G. SIMARD, I. HASEGAWA, W. BANDARUK, AND C. E. HEADINGTON. *Anal. Chem.* **23**, 1384 (1951).

As a part of the petroleum industry's pollution abatement program, a sensitive, accurate, infrared method has been devised for determining small amounts of oil and phenols in water. The method for phenols is based on bromination of the phenols, extraction of the resulting bromides from water with carbon tetrachloride and measurement of optical density of the extract at 2.84 microns. The oil determination is

based on optical density measurements of the same extract at the 3.4-micron region for specific carbon hydrogen radicals. The method is sensitive to 0.1 p.p.m. for the oil and 0.01 p.p.m. for the phenol.

R. S. INGOLS

Direct-Reading and Differential-Frequency Meter for High-Frequency Titrations. By W. J. BLAEDEL AND H. V. MALMSTADT. *Anal. Chem.*, **24**, 451 (1952).

Selecting the End Point in High-Frequency Titrations. *Ibid.*, 455.

In the titration of very turbid or highly colored solutions, it is frequently necessary to carry out a titration with instruments in order to detect an end point. Where the solution also contains material such as radioactivity and/or highly toxic substances, the problem of poisoning or contaminating the electrodes of the instrument must be considered.

The use of a high-frequency meter makes possible the titration of any solution that will give a difference in conductivity by adding the standard solution without the use of electrodes. This article describes the circuits used for building a high-frequency meter that can be used for titrations without any previous preparation of the sample for titrations.

The second article describes the applications that can be made of the high-frequency instrument mentioned in the first article. R. S. INGOLS

M.C.A. Committee Says Pollution Control Should be Self-Regulated. ANON. *Chem. Eng. News*, **30**, 985 (1952).

At the Conference of the Manufacturing Chemists Association on Air Pollution Abatement, it was stated that the chemical industry has spent more than $35,000,000 for equipment to abate air pollution. Gillet explained that his committee believes in self-regulation of air pollution, although it recognizes that in some areas conditions may require concerted action under government leadership.

Many phases of the problem of air pollution were discussed. It was defined as "the presence in the air of substances put there by acts of man in concentrations sufficient to interfere with comfort, safety, or health of man, or with the full use and enjoyment of his property." The equipment needed for aerosol measurement was presented by Munger, of Battelle Memorial Institute. Sulfur dioxide is the most important and most studied gas, whereas fluorides may be important in certain areas.

The importance of high smokestacks for disposing of noxious gases was stressed by G. R. Hill of American Smelting and Refining Co. The results of studies on wind tunnels by Strom of New York University were presented in some detail.

Gosline of du Pont stressed that pollution is easier and cheaper to avoid than to cure. R. S. INGOLS

Symposium on Liquid Industrial Wastes. *Ind. Eng. Chem.*, **44** (1952).

A symposium of 18 papers presented before the Diamond Jubilee Meeting, American Chemical Society, as follows:

Antibiotics. By J. M. BROWN AND J. G. Niedercorn. P. 468.

Wastes from the manufacture of antibiotics present a new and difficult disposal problem because of the presence of antibiotic substances along with large amounts of organic matter. Some products of value as supplements to animal feeds have been obtained as by-products, but much more work is needed in this direction to answer the whole problem. The antibiotics frequently result in the loss of ordinary, desirable flora in both filter beds and aeration tanks, but other organisms do develop. The results obtained in both laboratory and plant-scale tests given, with a discussion of the techniques that have been required for the particular problems. Modified biological processes are fairly successful, although only partly understood.

Atomic Energy Industry. By J. H. HAYNER. P. 472.

This is a review of the present status of the work with the wastes of the new nuclear energy industry. The ordinary industrial hygiene techniques are adequate for the production of the metal and compounds of uranium from its ore, as the radioactivity is of low intensity. The usual techniques for reclamation of dusts and settling of waste waters from these plants is adequate.

In the handling of high-level liquid radioactive wastes, a very small concentration of radioisotopes produces tolerance limits

of radiation. These levels must be reconciled with all of the environmental factors. The principle of concentration and confinement is the most likely approach to the resolution of these problems. Research on the improvement of these processes is under way, but much more work is needed.

Citrus Fruits Industry. By H. W. Von Loesecke. P. 476.

There are some very severe pollution problems in the citrus producing states of the southern U. S., as well as many less critical areas. The production of citrus molasses from the press liquor of citrus pulp has greatly aided solution of the problem of disposing of the concentrated liquid wastes of the industry.

The cannery effluents are much larger in number and in volume, but in general much lower in B.O.D. Treatment of these effluents in lagoons or lakes and rivers is generally used, although trickling filters have been studied.

Corn Products Manufacture. By E. M. Van Patten and G. H. McIntosh. P. 483.

The American Maize Co. reports in this article upon its program of reducing the loading of its plant effluent from an average of 350,000 population equivalents daily in 1944 to 28,000 in 1951. At present, approximately two-thirds of the effluent load is going through the Hammond (Ind.) Sanitary District sewage treatment plant.

This reduction in loading has required an investment of $850,000 to replace equipment which normally had years of service. Because of this new process and equipment, the company has experienced a 1 per cent increase in the over-all plant yield, worth approximately $175,000 a year at present market prices. Excellent cooperation of the operating personnel has permitted this improvement.

Dairy Industry. By H. G. Harding. P. 487.

Much progress has been made by the dairy industry in the reduction of B.O.D. in dairy waste waters by waste prevention and waste saving, because it is more economical than subsequent waste treatment. Any of the well-known waste disposal processes used for city wastes can be successfully used for dairy wastes, but are too costly for individual plants. Research is in progress to find an economical, satisfactory method of treatment.

Grain Distilleries. By C. S. Boruff. P. 491.

Beverage distillers are recovering, drying, and marketing most of their destarched grain stillage as distillers dried grains and dried solubles. Only 1 per cent of the stillage is wasted, whereas 14 per cent is fed to stock wet. Other liquid wastes from a modern distillery having complete stillage recovery are generally high in volume and can be treated effectively on trickling filters. Stabilization by anaerobic treatment is also possible.

Organic Chemicals Manufacture. By R. W. Hess and C. J. Carney. P. 494.

Much of organic chemicals manufacture was started on the utilization of residuals from the coking of coal and this spirit has permeated all subsequent developments. In general, the residuals from organic chemicals manufacture are comprised of not only reaction by-products, but also unconsumed raw materials, which include process aids such as solvents.

New chemical manufacturing plants are being built where management will not approve the installation for productive operations until adequate waste disposal has been incorporated in the design. Each process is carefully considered; monetary returns from recoveries are taken into account in deciding on whether the most economical solution of the pollution problem is in recovery, modification of the productive process, or waste treatment.

Pulp and Paper Industry. By H. R. Murdock. P. 507.

Wisconsin, Michigan, and Washington have recently ordered paper mills to reduce the degree of pollution caused by several paper mills in each state. Pulp and paper mills have done extensive research and now must prepare to apply the information. Most of the mills were ordered to remove the fiber from the waste water and others were ordered to further reduce their load.

Production of paper has almost doubled in the past 10 years, but new mills have demonstrated that modern methods and well-designed equipment can reduce stream pollution from the pulp and paper industry.

Packinghouses. By F. W. Mohlman and K. V. Hill. P. 498.

The wastes from packinghouses can be treated readily in conjunction with domestic sewage, but are rather strong for separate treatment by biological techniques. Chemical coagulation is effective in reducing the B.O.D. of wastes from small packinghouse operations, but is so expensive that it is not practical. Anaerobic treatment is being tried on a pilot scale.

Petroleum Refineries—Pollution Abatement at Sinclair Refining Company. By N. J. Gothard and J. A. Fowler. P. 503.

By using information gained by the American Petroleum Institute, this large refinery in the Chicago area has reduced the volume of its wastes by 95 per cent and its pollution load accordingly. All of its cooling water is re-used by employing cooling towers and many process changes within the plant have aided in solving the pollution problem.

Steel Industry. By R. D. Hoak. P. 513.

An outline is presented of the waste disposal and utilization practices in the steel industry. The prospects for economical recovery of by-products from wastes, other than those now being salvaged, are not promising. Meanwhile, the industry is making progress in eliminating wastes that contribute to stream pollution.

Tanneries. By J. W. Hornly. P. 520.

In general, tanneries are located in large cities and their wastes are discharged into the city sewers. Small tanneries have a difficult time to reduce their pollution load economically, although biological processes are generally effective and thoroughly studied. A good bibliography is included.

Waste Disposal in Britain. By B. H. Southgate. P. 524.

This paper covers briefly the status of industrial pollution of each of the major industries of Britain. The industrial wastes discharging to the inland waterways must have a B.O.D. less than 20 p.p.m., although wastes discharged to tidal waters need not be treated.

In a second major division of the paper, there is given a discussion of research on the biological filtration of sewage. The results obtained indicate that alternating double filtration will give as good or better results at higher loadings than single filtration or single filtration with recirculation. The studies on the frequency of dosing filters at a constant rate of flow indicates that there is no correlation between B.O.D. removal and the frequency with which a rotary distributor operates.

Removal of Color in Wastes. By W. Rudolfs and W. D. Henlon. P. 531.

Many factors influence the hue and intensity of color in an industrial waste. These include the light source energy distribution, the degree of light transmittance or reflectance by the waste, the pH of the waste liquor, the degree of treatment of the waste, and the sensitivity of the observer. The color characteristics of the waste may be expressed in terms of transmittancy curves, but the best color designation includes the hue, luminance, and purity.

Results given show that the color of a de-inking waste is mainly caused by reflection from the ink particles, but that the liquor also has color. Wastes from slaughterhouse, dye, and beet sugar plants have highly characteristic light transmittance curves, while paper mill, yeast, and antibiotic wastes are similar in color. Chlorination of a rope cooking liquor reduces the color and B.O.D. in proportion to the chlorine utilized.

Brass and Copper Industry—Cation Exchangers for Metals Concentration from Pickle Rinse Waters. By F. X. McGarvey, R. E. Tenhoor, and R. P. Nevers. P. 534.

Results are given of a small pilot plant study at a copper plant on the recovery of copper and brass alloy metals. It is indicated that the metals can be successfully recovered by a high-capacity exchanger resin such as Amberlite IR-120. Either the sodium or hydrogen cycle may be used; the hydrogen cycle takes more expensive equipment, but leads to an easier use or recovery of the regenerant solution. Where the rinse water is dilute, the major factor influencing capacity for copper and zinc is the relative amount of calcium and magnesium in the raw-water supply.

From the data presented, it is evident that the recovery of the copper and zinc

can be profitable, especially when a high concentration of these metals is maintained in the liquor to the ion exchanger. Where recovery is not wanted, the sodium cycle should be used; but even here recovery is possible by chemical treatment of the regenerant solution.

Sulfuric Acid Recovery from Waste Liquors. By F. J. Bartholomew. P. 541.

Because of the short supply of sulfur and the need for reduction in stream pollution by strong acid wastes, consideration is given to the possible techniques of recovering acids from process waste liquors. Technically, sulfuric acid can be readily recovered from pickle liquor or titanium pigment liquor, but the profitable installation of acid recovery lies in a higher price of sulfuric acid and possible necessity of reducing the amount of sulfuric acid dumped into the stream.

Wastes Containing Radioactive Isotopes. By C. C. Ruchhoft, A. E. Gorman, and C. W. Christenson. P. 545.

This article describes the actual plant at Los Alamos, N. Mex., which is the result of laboratory studies reported earlier [see This Journal, 23, 11, 1463 (Nov., 1951)]. Operating results indicate that plutonium can be removed to produce a water permissible to drink at a cost of 0.8¢ per gallon. Coagulation and carrier precipitation procedures common to municipal water purification practice have been applied to the treatment of low-level radioactive plutonium wastes.

Mechanism of Methane Fermentation. By A. M. Buswell and H. F. Mueller. P. 550.

Data show that methane can be produced by several organic chemical mechanisms. Acetic acid is decarboxylated to methane and carbon dioxide. With methyl alcohol and formic acid, some carbon atoms are oxidized to carbon dioxide, some are reduced to methane. With propionic acid, water is also needed to complete the breakdown of the molecule to methane and carbon dioxide.

Other simple organic molecules and hydrogen can reduce carbon dioxide to produce methane plus some other product (acetic acid), which is itself broken down to methane and carbon dioxide.

Hydrocarbons and ethers have not been fermented to methane. D-limonene is an active inhibitory reagent to methane fermentation. R. S. Ingols

Aeration with High-Oxygen Atmosphere in the Activated Sludge Process. By Harold E. Babbitt. Civil Eng. Studies, San. Eng. Series No. 2, Univ. of Illinois, 10 pp., mimeo. (Nov. 15, 1951).

If oxygen is the essential element in the efficacy of aeration in activated sludge plants, the author believed that a reduction in the required volume of air, a reduction in agitation, accelerated oxidation, and other beneficial effects might result from the aeration of mixed liquor in an enclosed tank using a synthetic atmosphere containing a high proportion of oxygen. Apparatus to determine whether the addition of oxygen in such a manner is economically feasible was devised and tested.

The flow pattern was the same as for standard activated sludge treatment, except that the mixed liquor entered the bottom of a closed aeration tank and rose with the gas bubbles to the top of the tank, from which it flowed to an open final settling tank.

The aerating gas was circulated in a closed system with frequent sampling of the gas to determine its oxygen content. Pure oxygen was added to the closed gas system to maintain the desired percentage of oxygen in the gas.

Tests were made with a 3-hr. aeration period, 30 per cent returned sludge with 1 to 1.5 per cent solids, and 95 per cent oxygen in the gas used for aeration. Aeration rates varied from 0.3 to 2.0 cu. ft. per gal. of sewage treated.

Results were inconclusive and no reliable data were obtained because of the difficulty in maintaining the desired oxygen concentration in the gas. It had not been foreseen that aeration with an oxygen-rich gas mixture would wash nitrogen out of the sewage into the gas. It was found necessary to purge the closed gas system of accumulated nitrogen frequently, with a consequent loss in oxygen.

Cost estimates indicated that, if the plant had worked, the use of oxygen would have been five-fold more costly than standard activated sludge treatment. It was concluded that "any attempt to use an oxygen-enriched atmosphere in the activated sludge process is economically unjus-

tifiable. . . ." Cost estimates were based on an oxygen cost of $100 per ton and a saving in aeration tank capacity of 50 per cent.

Abstractor's comment—The paper indicates that the utilization of oxygen in the standard activated sludge process is not economically feasible. To make economical use of oxygen gas in biological sewage treatment it would be necessary to use a process flow pattern substantially different from that of the activated sludge process. Furthermore, the only oxygen that can be considered feasible for sewage treatment is the low-cost, 95 per cent pure, "tonnage" oxygen manufactured at or near the plant site. Depending upon the size of the installation, this oxygen would cost about $10 to $20 per ton today.

DANIEL A. OKUN

Summary Report on Water Pollution; Upper Mississippi Drainage Basin. U. S. Pub. Health Serv. Publ. No. 150 (1951).

Sewage and waste treatment projects are recommended at 921 municipal and industrial locations in an area extending to eight states. The needed projects include 705 for municipalities and 216 for industries. Municipalities need 329 new treatment plants, enlargements or additions to 225, and replacement of 151 plants. Industry needs 143 new plants, enlargements or additions to 46, and 27 replacements.

No projects are needed at 579 municipal and 126 industrial locations. Of the municipalities having sewer systems, 70 per cent also have sewage treatment facilities. Of the industries listed, 32 per cent are known to have some type of treatment facilities. H. P. ORLAND

Summary Report on Water Pollution; Southeast Drainage Basins. U. S. Pub. Health Serv. Publ. No. 153 (1951).

In the Southeast Drainage Basins, extending to 9 states, sewage and waste treatment projects are recommended at 774 municipal and industrial locations. The 654 needed municipal projects are estimated to cost $108,000,000; the 120 needed industrial projects are estimated to cost $150,000,000. Municipalities need 466 new treatment plants, enlargements or additions to 147, and replacement of 41 plants. Industry needs 110 new plants and enlargements or additions to 10.

No projects are needed at 401 municipal and 59 industrial locations, but project needs are undetermined for 282 municipalities and 988 industries. Of the municipalities having sewer systems, 66 per cent have some type of sewage treatment facilities, but treatment provided by many of these is considered inadequate. Less than 7 per cent of the industries listed as having separate wastes outlets are known to have some type of treatment facilities.

H. P. ORLAND

Summary Report on Water Pollution; Western Gulf Drainage Basin. U. S. Pub. Health Serv. Publ. No. 92 (1951).

Treatment projects estimated to cost $56,344,000 are needed at 255 municipal locations in the basin. No estimate is given of the cost or number of required industrial waste treatment plants, because of the complexities involved in the problem of treatment processes. H. P. ORLAND

Tentative Standard Specifications for Reinforced Concrete Water Pipe—Noncylinder Type, Not Prestressed. 16 pp. Price, 20¢. Amer. Water Works Assn., New York, N. Y. (1951).

The specifications, known as AWWA/# C302-51T, cover manufacture of unprestressed concrete pipe of noncylinder reinforced type in sizes from 12 to 96 in. This type of pipe is designed for service in which the maximum design head does not exceed 100 ft. H. P. ORLAND

Radiological Monitoring Methods and Instruments. Nat. Bur. of Stand. Handbook 51. U. S. Govt. Printing Off., Washington, D. C. Price, $0.15 (1952).

No attempt is made in this handbook to provide a complete manual on radiological instruments. It does, however, indicate the types of measurements and instruments necessary for determining the adequacy of radiation shielding in low-voltage and high-voltage X-ray installations, radioactivity laboratories, radium handling areas, etc.

H. P. ORLAND

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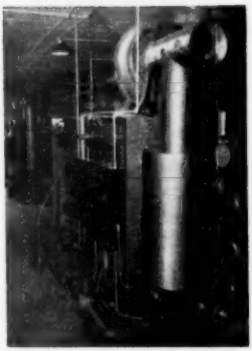
Henry B. Steeg & Associates, Indianapolis, Indiana were consulting engineers. W. E. Ross is superintendent of the plant.



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Proceedings of Member Associations

MARYLAND-DELAWARE WATER AND SEWERAGE ASSOCIATION

The Silver Anniversary meeting of the Maryland-Delaware Water and Sewerage Association was held at the Wardman Park Hotel, Washington, D. C., April 17–18, 1952.

The technical sessions featured the following papers:

"Landscape Design and Planting for Water and Sewage Plants," by Henry Schultheis, Washington, D. C.

"Some Activities of the Interstate Commission on the Potomac River Basin," by Edwin R. Cotton, Director.

"Development of Water and Sewerage Facilities in Baltimore County," by John B. Funk, Towson, Md.

"Organic Garbage Disposal," by Les Flynt, American Composter Co., Lansing, Mich.

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1st Vice-President: Roy H. Ritter, Baltimore, Md.
2nd Vice-President: E. F. Donaldson, Annapolis, Md.
Secretary-Treasurer: W. McLean Bingley, Baltimore, Md.

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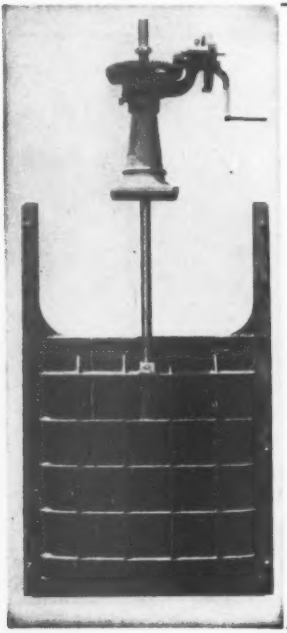
Secretary-Treasurer



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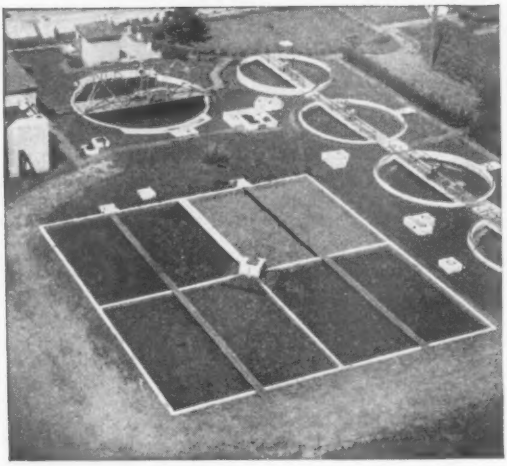

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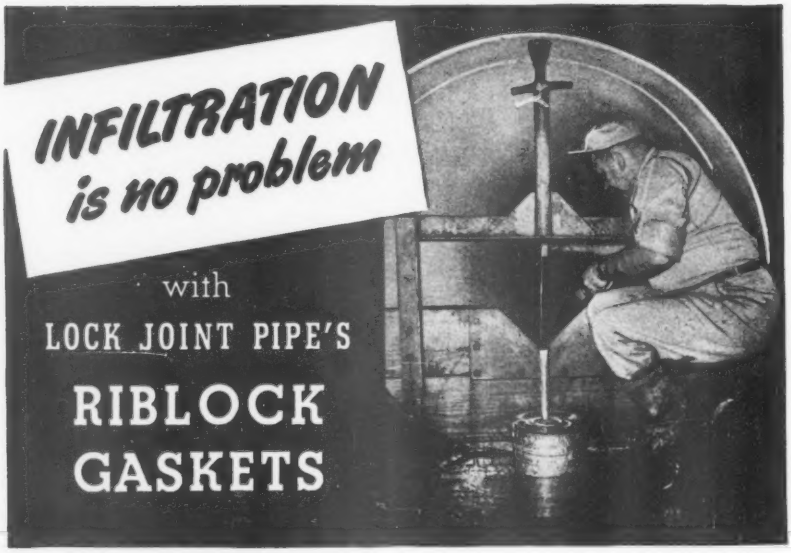

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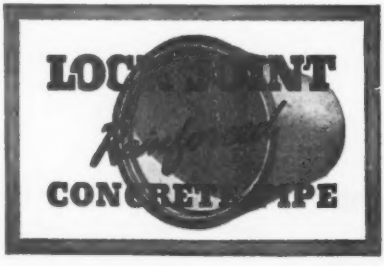

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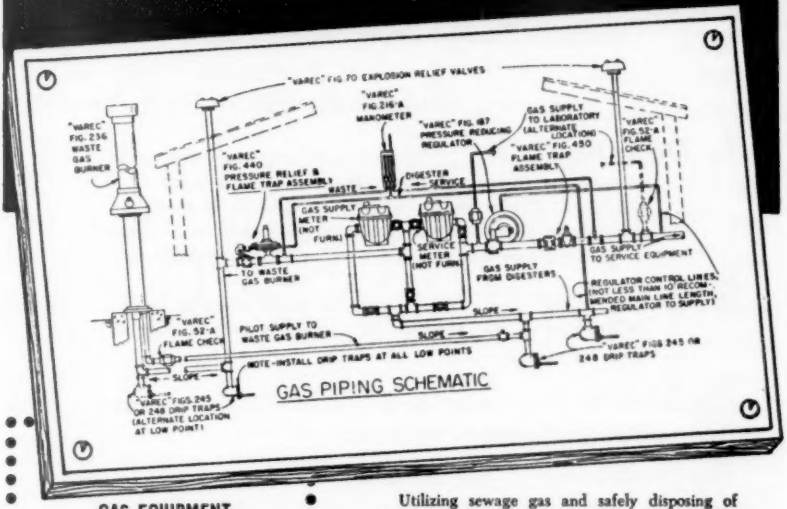
"VAREC" FIG. 70 EXPLOSION RELIEF VALVES
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
"VAREC" FIG. 187 PRESSURE REDUCING REGULATOR
GAS SUPPLY TO LABORATORY (ALTERNATE LOCATION)
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
"VAREC" FIG. 52-A FLAME CHECK
WASTE
DIGESTER SERVICE
GAS SUPPLY METER (NOT FURN.)
SERVICE METER (NOT FURN.)
GAS SUPPLY TO SERVICE EQUIPMENT
TO WASTE GAS BURNER
GAS SUPPLY FROM DIGESTERS
REGULATOR CONTROL LINES (NOT LESS THAN 10' RECOMMENDED MAIN LINE LENGTH, REGULATOR TO SUPPLY)
"VAREC" FIG. 52-A FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
SLOPE
SLOPE
NOTE-INSTALL DRIP TRAPS AT ALL LOW POINTS
"VAREC" FIGS. 245 OR 248 DRIP TRAPS
"VAREC" FIGS. 245 OR 248 DRIP TRAPS (ALTERNATE LOCATION AT LOW POINT)
GAS PIPING SCHEMATIC

GAS EQUIPMENT SPECIFICATIONS

a. **PRESSURE RELIEF AND FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 440

b. **FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 450

c. **FLAME CHECK**
"VAREC" Fig. No. 52A

d. **EXPLOSION RELIEF VALVES**
"VAREC" Fig. No. 70-1

e. **WASTE GAS BURNER**
"VAREC" Fig. No. 236

f. **DRIP TRAPS**
"VAREC" Fig. No. 245 (automatic)
"VAREC" Fig. No. 248 (hand operated)

g. **MANOMETERS**
"VAREC" Fig. No. 216A

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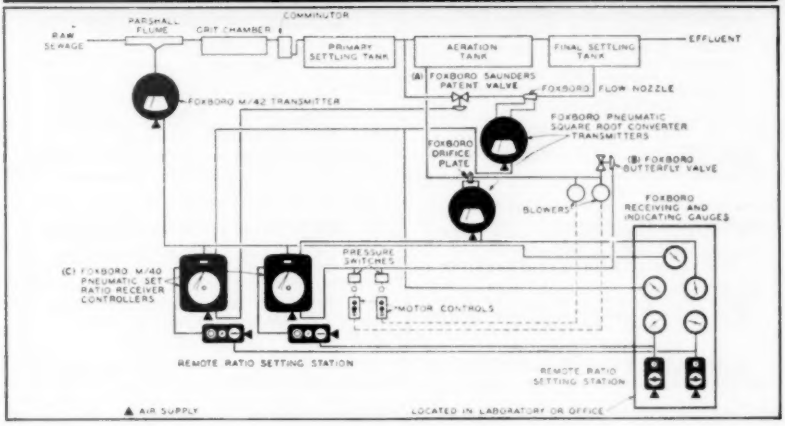

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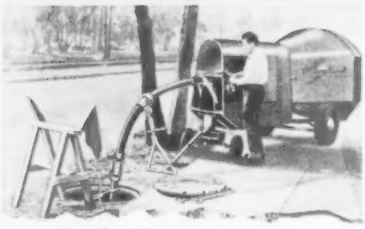

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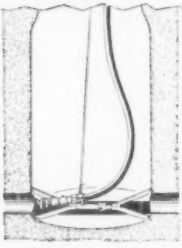

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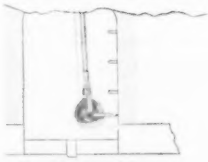

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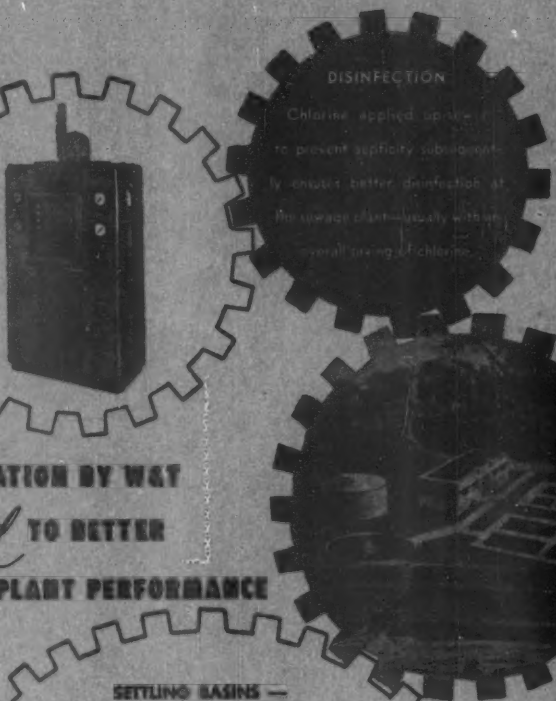

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